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METEOROLOGICAL PREDICTION FOR NUCLEAR EMERGENCY RESPONSE: ANALYSIS OF 1988/1989 PICKERING MESONET DATA

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ABSTRACT

Data for 1988 and 1989 from the Pickering Mesonet meteorological monitoring network were analyzed to determine trends in local meteorology in the vicinity of Pickering NGS. The intent of this work is to develop site-specific information to assist meteorologists in predicting local wind directions in the event of a nuclear emergency. Trends in the Wind Persistence Factor (WPF) and the Wind Variation Band (WVB) for the Pickering area with wind speed, time of day and synoptic category were identified and quantitative estimates of the WVB and the WPF under various conditions have been obtained.

1.0 INTRODUCTION

Nuclear emergency response procedures established for Ontario require that meteorologists forecast meteorological conditions at the site of the emergency. Local meteorological parameters that must be forecast include wind speed, wind direction, the standard deviation (SD) of wind direction, cloud cover, temperature and precipitation. Forecast meteorological parameters will be input to an atmospheric dispersion model to predict the concentrations and dimensions of any release plume

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which will, in turn, determine the potential radiation dose within the response sectors surrounding the facility. Ontario procedures require that protective actions (sheltering, evacuation, etc) be taken in these response sectors if the ***projected*** radiation dose within the sector exceeds the Protective Action Level (PAL) for that action; hence the need for projections to allow decision making.

Ontario procedures also call for the estimation of the persistence of plume direction over the dose projection period (a four hour period beginning one hour after the time at which the projection is made). The persistence of plume direction is defined by the Ontario Ministry of the Solicitor General (MOSG) in terms of the Plume Persistence Factor (PPF) and the Plume Variation Band (PVB) as follows:

> **The Plume Persistence Factor (PPF).** "The largest fraction of the projection period during which the plume centreline can be expected to remain, up to the Primary Zone boundary, in any one direction $\pm$ 10°. Expressed as 1.0 for the whole projection period, 0.5 for half the period, etc.
>
> It would depend on the expected persistence of the wind direction, the size of the expected wind shifts, etc. When the factors cannot be assessed reasonably accurately the Factor will be taken as 1.0."
>
> **The Plume Variation Band (PVB).** "The angular sector within which the plume centreline can be expected (at the 95% confidence level) to remain, up to the Primary Zone boundary, during the projection period. It is expressed as $\pm$ X° in relation to the plume centreline bearing assumed for the projection period. It would be based on such factors as inherent errors in wind direction measurements, inaccuracies in predicting future wind directions, and likely variations during the projection period due to wind shifts, plume meander, local effects, etc".

The PVB is intended to account for "all possible sources of uncertainty in wind direction [and hence plume direction] during the four-hour projection period" (Pilt, 1990). The PVB thus determines the angular sector potentially impacted by the plume and it is assumed that the plume centreline dose as predicted by the model could occur anywhere in the region defined by the PVB. The PPF is intended to "reduce the extreme conservatism introduced by the assumption that the entire surface area defined by the PVB receives the maximum [plume] centreline dose" (Pilt, 1990). The plume centreline dose as calculated by the plume model is thus multiplied by the PPF to correct for the fact that the model predicts one-hour averages whereas the projection period is four hours.

The PVB and PPF are non-standard meteorological parameters. Ontario Hydro meteorologists have no experience in predicting the PVB and PPF and hence a need to develop methods to aid in the prediction of the PPF and PVB was identified.

After discussions between the Meteorology Section of Power System Operations Division and the Environmental Physics and Chemistry and Operations Research Sections of Research Division the following projects were initiated:

1. To analyze historical data obtained at a nuclear generating site to establish quantitative information on local meteorological trends over the projection period (ie, to establish statistical relationships between meteorological conditions up to and including the present and meteorological conditions in the following one to five hours, which is the dose projection period).

2. To explore the use of neural networks trained on historical data obtained at a nuclear generating site to predict wind direction.

The present report deals with the first project. Work undertaken in regard to the second project will be reported separately (Ramani 1991).

2.0 METHODS

The Pickering Mesonet

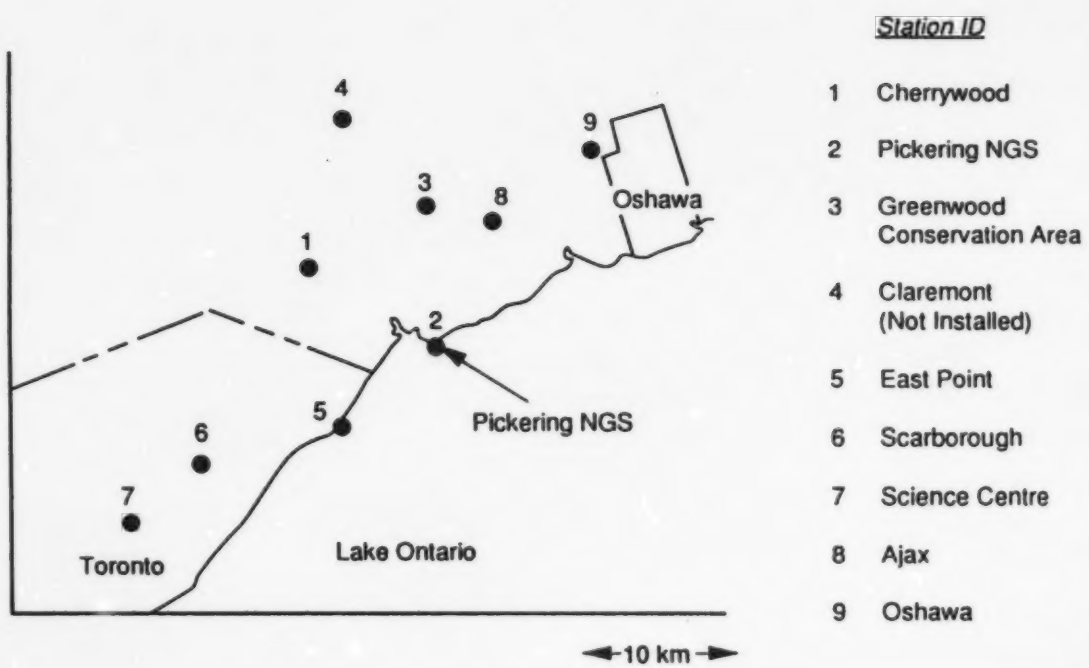
The data records selected for analysis were from the Pickering Mesoscale Meteorological Monitoring Network (Mesonet) operated by Atmospheric Environment Service (AES) of Environment Canada over 1988 and 1989 with support from the Ontario Ministry of the Environment, the Atomic Energy Control Board and Ontario Hydro (Salmon et al., 1990; Ogram and Middleton, 1990). The Mesonet comprised eight 10-m meteorological towers located within a 30 km radius of Pickering NGS (as shown in Figure 1). Data records from the Mesonet include mean scalar wind speed, mean vector wind speed, standard deviation (SD) of wind speed, peak wind speed, wind direction, SD of wind direction, temperature, relative humidity (RH) and barometric pressure.

Data records from the Mesonet were converted to a form suitable for analysis. The format of the processed data files is shown in Table 1. Files were created for all eight sites.

The data base was augmented by adding synoptic information derived from weather maps. The method proposed by Lindsey and Glance (1986) for the US Nuclear Regulatory Commission was adopted for classifying synoptic meteorological conditions. The system assigns numbers to synoptic categories according to the system described in Table 2. Synoptic data (four numbers for each hour corresponding to synoptic category, orientation of surface isobars, magnitude of surface pressure gradient, and persistence of synoptic category, respectively) were derived from analysis of weather maps by the Meteorology Section and entered into the Pickering 1988 data file.

Three Mesonet sites were chosen for initial analysis: Cherrywood, Pickering and East Point (sites 1, 2 and 5, respectively, in Figure 1). These sites were chosen with the intent of investigating the similarities between two lakeshore sites (one close to Pickering NGS and one located west of Pickering NGS), and the differences between these two lakeshore sites and a site further inland.

It was also decided to restrict initial analysis to the PPF and PVB (because of the lack of methods for predicting these factors) and their dependence on likely controlling variables such as wind speed, time of day, season, and synoptic category. Other key meteorological variables (such as wind speed and direction, and SD of wind direction) requiring projection were to be considered at a later stage, after assessing the results for PVB and PPF.



Station ID

1 Cherrywood
2 Pickering NGS
3 Greenwood Conservation Area
4 Claremont (Not Installed)
5 East Point
6 Scarborough
7 Science Centre
8 Ajax
9 Oshawa

FIGURE 1

LOCATIONS OF PICKERING MESONET STATIONS

TABLE 1. Format of Processed Mesonet Files (S**S198*.DAT)

Stn.	Jul. Day	Hour	Scalar Wind Speed	St. Dev. of (-----	Maximum Wind Speed	Vector Wind Speed	Wind Direction	St. Dev. of (-----	Temper.	Relative Humidity	Barom. Pressure
1	1	0	-999.9999	-999.9999	-999.9999	-999.9999	-999.9999	-999.9999	-999.9999	-999.9999	-999.9999
1	1	1	4.3000	1.1900	8.2000	4.1600	269.0000	14.3000	-1.1000	64.0000	99.6500
1	1	2	5.8900	1.4800	10.1500	5.7200	259.0000	13.1000	-1.4000	64.0000	99.6800
1	1	3	4.8700	1.3700	8.9800	4.6900	262.0000	13.5000	-1.8000	64.0000	99.7400
1	1	4	5.0600	1.4500	9.1700	4.8900	259.0000	13.8000	-2.1000	66.0000	99.7800
1	1	5	6.3900	1.5000	11.0800	6.2200	249.0000	13.0000	-2.5000	65.0000	99.8100
1	1	6	6.6000	1.5900	11.4200	6.4200	248.0000	11.9000	-2.9000	65.0000	99.8500
1	1	7	6.0100	1.4900	10.1700	5.8700	251.0000	12.2000	-3.2000	65.0000	99.9300
1	1	8	6.2300	1.7200	11.2200	6.0700	252.0000	12.4000	-3.6000	66.0000	100.0100
1	1	9	6.7500	1.6700	11.7100	6.5800	252.0000	12.7000	-3.9000	67.0000	100.0800
1	1	10	5.3800	1.2700	8.9700	5.2700	247.0000	11.5000	-4.4000	80.0000	100.1600
1	1	11	6.7500	1.7600	11.4400	6.5900	246.0000	12.3000	-3.8000	69.0000	100.2200
1	1	12	6.8300	2.0100	12.8900	6.5900	253.0000	14.7000	-3.6000	59.0000	100.2300
1	1	13	7.2500	1.7800	12.9000	7.0500	251.0000	12.7000	-4.2000	56.0000	100.1800
1	1	14	8.3600	2.0800	14.3500	8.1400	250.0000	12.7000	-4.0000	48.0000	100.1700
1	1	15	8.7800	2.2200	15.1300	8.5200	252.0000	12.7000	-4.2000	47.0000	100.1900
1	1	16	7.9900	2.0900	14.2200	7.7600	258.0000	13.5000	-5.7000	51.0000	100.2700
1	1	17	7.4600	1.8300	13.1500	7.2300	257.0000	13.3000	-6.8000	50.0000	100.3300
1	1	18	7.3600	1.8600	12.7600	7.1700	255.0000	12.8000	-7.9000	56.0000	100.4100
1	1	19	6.6600	1.7600	11.9100	6.4900	251.0000	12.5000	-8.5000	59.0000	100.4800
1	1	20	7.1800	1.8700	12.5900	7.0200	250.0000	11.9000	-8.6000	60.0000	100.5200
1	1	21	6.6200	1.5700	11.0500	6.4900	250.0000	11.3000	-8.7000	61.0000	100.5600
1	1	22	5.5300	1.2600	9.0300	5.4000	256.0000	12.1000	-8.8000	66.0000	100.6200
1	1	23	5.8200	1.5100	10.7300	5.6400	257.0000	13.0000	-8.7000	69.0000	100.6600
1	2	0	5.9300	1.4900	10.3000	5.7900	255.0000	12.5000	-9.1000	66.0000	100.7300
1	2	1	6.2700	1.6200	11.1900	6.1200	253.0000	12.5000	-9.3000	58.0000	100.7900
1	2	2	6.0500	1.5800	10.8100	5.8900	259.0000	12.7000	-9.5000	59.0000	100.8600
1	2	3	5.9100	1.3500	9.9500	5.7900	250.0000	11.2000	-9.9000	61.0000	100.9100
1	2	4	4.6900	1.1200	8.0200	4.5900	252.0000	11.5000	-10.2000	64.0000	100.9600
1	2	5	4.1000	0.9700	6.9900	4.0100	252.0000	12.3000	-10.2000	66.0000	100.9900
1	2	6	3.5400	0.8300	5.9400	3.4700	247.0000	11.0000	-9.6000	65.0000	101.0200
1	2	7	3.7700	0.8200	6.2200	3.6900	250.0000	11.6000	-9.2000	64.0000	101.0500
1	2	8	4.4600	1.0400	7.2700	4.3400	248.0000	11.7000	-9.1000	61.0000	101.1100
1	2	9	5.1300	1.1700	8.6600	5.0100	238.0000	11.5000	-8.6000	63.0000	101.1800
1	2	10	4.5700	1.2200	7.7800	4.3800	261.0000	14.8000	-7.7000	56.0000	101.2100
1	2	11	4.4200	1.0600	7.5100	4.2700	231.0000	12.8000	-6.9000	59.0000	101.2300
1	2	12	4.5700	1.0200	7.3800	4.3900	231.0000	12.9000	-6.5000	58.0000	101.1800
1	2	13	4.9100	1.1300	8.1200	4.7100	239.0000	15.1000	-5.8000	52.0000	101.0800
1	2	14	5.4900	1.4000	9.3600	5.2800	249.0000	15.2000	-5.0000	48.0000	101.0300
1	2	15	5.9300	1.4400	9.9200	5.7400	247.0000	13.4000	-4.9000	47.0000	100.9600
1	2	16	5.5100	1.2200	8.7500	5.3300	247.0000	13.3000	-5.5000	49.0000	100.9300
1	2	17	3.3000	0.7800	5.9400	3.2300	241.0000	10.6000	-6.6000	55.0000	100.9300
1	2	18	1.8500	0.3500	2.9400	1.7700	255.0000	10.4000	-8.9000	65.0000	100.9300
1	2	19	4.0000	0.8100	6.7300	3.9400	234.0000	9.3000	-7.5000	60.0000	100.9400
1	2	20	5.4900	1.3000	9.0900	5.3900	235.0000	11.0000	-6.9000	60.0000	100.9700
1	2	21	4.8000	1.0300	7.8500	4.7200	240.0000	10.8000	-7.1000	61.0000	100.9800
1	2	22	3.4000	0.7400	5.6500	3.3400	242.0000	10.1000	-7.7000	64.0000	100.9500
1	2	23	3.2800	0.6900	5.3900	3.2300	240.0000	9.9000	-7.8000	64.0000	100.9600
1	3	0	3.4900	0.8700	6.2100	3.4200	249.0000	11.7000	-7.1000	62.0000	100.9600
1	3	1	3.1800	0.7000	5.4100	3.1200	251.0000	11.2000	-7.0000	60.0000	100.9500
1	3	2	1.6600	0.4100	2.9700	1.6100	264.0000	11.7000	-7.9000	63.0000	100.9300
1	3	3	1.1900	0.2800	2.2300	1.1600	243.0000	11.1000	-10.0000	71.0000	100.9500
1	3	4	2.3000	0.4700	3.8700	2.2700	242.0000	9.0000	-9.2000	69.0000	100.9400
1	3	5	1.7500	0.3400	2.7000	1.7100	227.0000	10.2000	-8.7000	68.0000	100.9200
1	3	6	2.6700	0.5400	4.4300	2.6300	232.0000	9.5000	-8.3000	66.0000	100.9400
1	3	7	3.1400	0.5600	4.9900	3.0600	240.0000	10.0000	-7.1000	60.0000	100.9400
1	3	8	2.2200	0.4400	3.6200	2.1700	264.0000	11.9000	-7.5000	60.0000	100.9400
1	3	9	0.8500	0.2900	1.7400	0.7800	245.0000	19.6000	-9.3000	68.0000	100.9700
1	3	10	2.1500	0.4700	3.5100	2.1000	236.0000	9.9000	-6.8000	63.0000	100.9600
1	3	11	3.4300	0.6900	5.1900	3.3600	227.0000	10.8000	-3.3000	51.0000	100.9500

TABLE 2

DEFINITION OF PARAMETERS USED IN THE WEATHER-TYPING MODEL

(from Lindsey and Glance, 1986)

Synoptic Category

1 = The warm sector of an extratropical cyclone with cyclonic curvature of surface isobars

2 = The region ahead of a warm front with cyclonic curvature of surface isobars.

3 = The region behind a cold front with cyclonic curvature of surface isobars.

4 = Under the influence of a cold core ridge with anticyclonic curvature of surface isobars.

5 = Under the influence of a warm core subtropical ridge with anticyclonic curvature of surface isobars.

Orientation of Surface Isobars (pressure gradient in streamline coordinates)

1 = N	337.5°	-	22.5°
2 = NE	22.5°	-	67.5°
3 = E	67.5°	-	112.5°
4 = SE	112.5°	-	157.5°
5 = S	157.5°	-	202.5°
6 = SW	202.5°	-	247.5°
7 = W	247.5°	-	292.5°
8 = NW	292.5°	-	337.5°

Magnitude of Surface Pressure Gradient (longitudinal separation of surface isobars)

1 = 1-2 degrees latitude*	strong
2 = 2-4 degrees latitude	
3 = 4-6 degrees latitude	moderate
4 = 6-10 degrees latitude	
5 = 10-20 degrees latitude	weak
6 = >20 degrees latitude	

*Assumes ~111 km/degree latitude

Persistence of Synoptic Category Between 3-Hourly Surface Map Observations

0 = S valid only at observation time.
1 = S valid 1 hour earlier.
2 = S valid 2 hours earlier.
3 = S valid 3 hours earlier (no change in synoptic category since last observation)
4 = unable to determine persistence

Potential input variables (ie, observed data on which to base projections) and output parameters (ie, parameters that need to be projected or forecast) that can be studied using the Mesonet data are listed in Table 3.

TABLE 3

Potential input	Required output
season	wind speed
month	wind direction
time of day	SD of wind direction, σ_θ
cloud cover	PVB
wind speed	PPF
wind direction	
SD of wind direction, σ_θ	
synoptic category	

The time scale for meteorological projections in the event of a nuclear emergency in Ontario is illustrated in Figure 2. We denote the time by which all projections must be available as P-hour. In order to make the necessary meteorological projections the meteorologist has available hourly-average meteorological data up to and including the hour beginning P-2, and will have real time information, as well as information time averaged over a period less than an hour, for the hour beginning P-1. The meteorologist is required to make projections for hours P+1 through P+4, inclusive (the ***projection period***).

For the present work, it was decided to analyze trends in the meteorological conditions in the projection period as a function of conditions in the hour P-1. (The alternative was to use conditions in the hour P-2 as a reference but the former approach was preferred on the basis that the meteorologist would likely have good information available on such parameters as wind speed and synoptic category for the more recent conditions during hour P-1, even if full one hour average values were not available). We thus refer to the hour beginning at P-1 as the ***reference hour***.

In attempting to analyze Mesonet data for information regarding the PPF and the PVB it became apparent that the definitions of the PPF and the PVB present problems.

Both the PPF and PVB refer to plume direction. The wind direction controls plume direction but may vary with height (wind direction shear) and with position (inhomogeneity of the wind field). In this analysis, we used the wind direction measured at 10 m by the Mesonet towers. In describing results, we therefore refer to the ***Wind Persistence Factor*** (WPF) and the ***Wind Variation Band*** (WVB) to emphasize that we are dealing with wind directions.

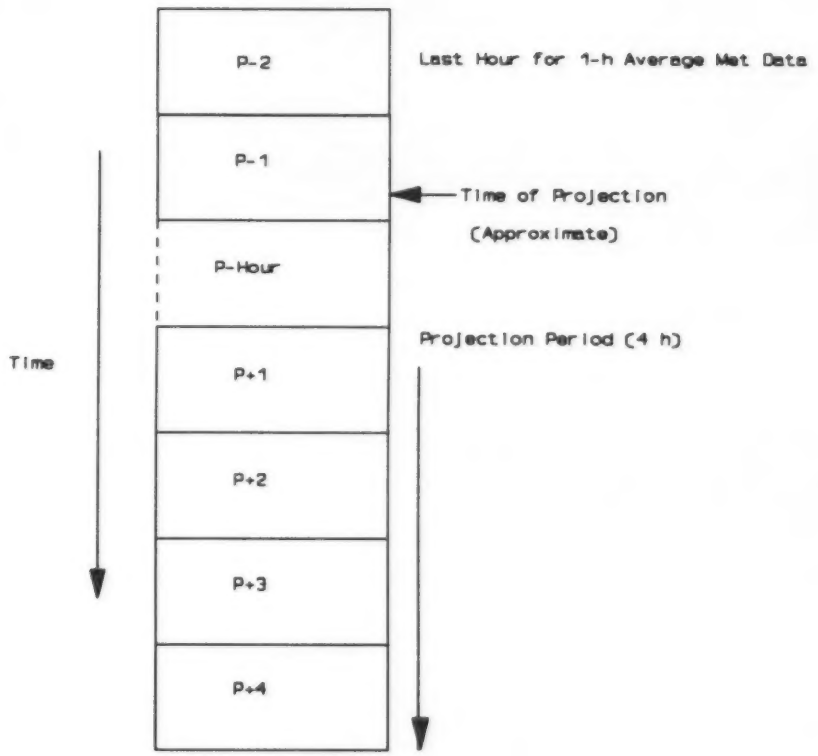


Figure 2. Illustrating the projection period (hours P+1 to P+4, inclusive) established for nuclear emergency response in Ontario.

As defined, the PVB is also difficult to determine rigorously from historic data as it includes both objective information (actual variation in wind direction over the projection period and error in wind direction measurements) and subjective information (inaccuracies in predicting future wind direction). After consideration, we suggest the following more robust definition which can be directly linked to historical data.

> The ***Wind Variation Band (WVB)*** is the largest angular sector defined by any two of the four one-hour average wind direction vectors for each of the hours of the projection period (ie, P+1, P+2, P+3 and P+4).

The WVB as defined in this way is illustrated in Figure 3. The full angular sector is taken rather than an angular deviation about the mean wind during the projection period (as in the definition of the PVB) because the variation of the wind about the four-hour-mean wind direction may not be symmetrical. Use of the one-hour average wind direction vector appears appropriate as the atmospheric dispersion model implemented for nuclear emergency response predicts one-hour average plume profiles.

The above definition of the WVB has the following advantages:

- WVBs defined in this way are well defined and are readily determined from historical data.
- The wind direction averaged over the four-hour projection period must necessarily be within the WVB (ie, the range defined by the one-hour average wind vectors). The WVB thus bounds the 4-h average wind direction.

In a similar way, for the purposes of the present analysis, the ***Wind Persistence Factor (WPF)*** was taken as the number of hours during the projection period where any of the four one-hour average wind direction vectors were within $\pm$ 10° of each other. The minimum and maximum values of the WPF are, therefore, 1 and 4, respectively (corresponding to fractions of the projection period of 0.25 and 1).

The WVB and WPF were calculated for every hour for which data were available at the reference hour and during the projection period for the Pickering, East Point and Cherrywood sites. Calculated WPF's and WVB's were then classified in terms of various parameters (as measured at the reference hour) and averaged to examine trends. In determining representative averages, the distributions of the WVB and the WPF were assumed to be lognormal (a lognormal distribution is more suitable than a normal distribution in the case where the parameters are constrained to be non-zero and the variation may be of the order of the mean value), hence the geometric means (GM) and the geometric standard deviation (GSD) were calculated. All results are tabulated in Appendix A. Results of specific interest are discussed below.

3.0 RESULTS

Relation of Wind Persistence Factor (WPF) to Wind Variation Band (WVB)

Wind persistence, as reflected in the WPF, and variation in wind direction, as reflected in the WVB, would be expected to show an inverse relationship. To examine this, values of WPF were grouped according to WVB, and the GM and GSD of the WPF were calculated. Results are shown for the

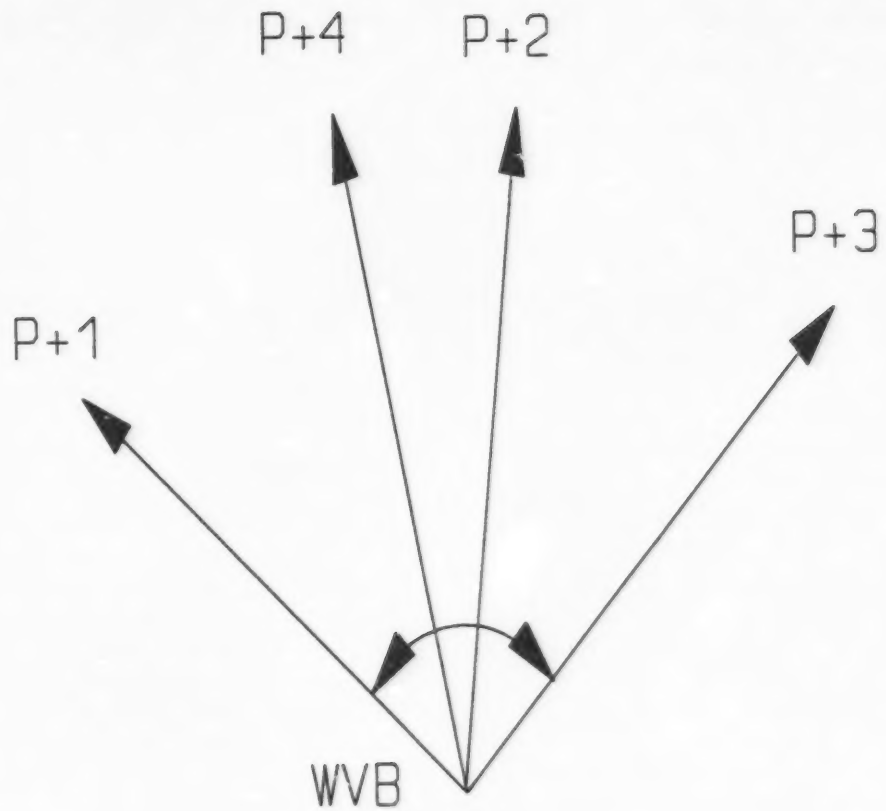


Figure 3. Illustrating the Wind Variation Band (WVB) as defined with respect to the 1-h average wind directions over the 4-h projection period (hours P+1 to P+4).

three sites in Figures 4a and 4b, for the years 1988 and 1989, respectively. The relationship between mean WPF and WVB was very similar for all sites, and for both years. As expected, the WPF decreased as WVB increased. The GSD of the WPF was typically about 1.4 indicating that 95% of the values were within a factor of ~2 (a factor equal to the GSD^2) of the mean.

WVB and WPF Versus Time After Sunrise

As atmospheric circulation is largely driven by solar radiation it was decided to examine the dependence of WVB and WPF on time after sunrise (TASR) as calculated from the date and time of day. The parameter TASR also reflects, to some degree, the effects of season. Results (GM versus TASR; all hours for years 1988 and 1989, respectively) for the three sites are given in Figures 5a and 5b, and 6a and 6b. Note that the time given refers to the *reference hour* and hence the WVB reflects wind direction variations in the following one to five hour period. The figures show similar trends at all sites with little change between 1988 and 1989.

Mean values of the WVB ranged between approximately 18° and 35°. Values of the WVB were slightly higher at the inland site (Cherrywood) than at the lakeshore sites (East Point and Pickering). Mean values of WVB showed a diurnal variation. Peaks in the WVB occurred near sunrise and sunset and minima in the WVB were associated with continuous daytime and nighttime conditions. At all sites, the WVB decreased after sunrise to a minimum at about 5 h. The WVB then increased again and peaked at about 8 to 12 h after sunrise (the peak occurred earlier at the lakeshore sites than at Cherrywood), then decreased to a minimum at about 15 to 20 h after sunrise, thereafter increasing to a maximum level to complete the cycle.

Figures 6a and 6b show that the WPF exhibited an inverse diurnal pattern to the WVB with mean values of the WPF ranging between approximately 2.1 and 2.7.

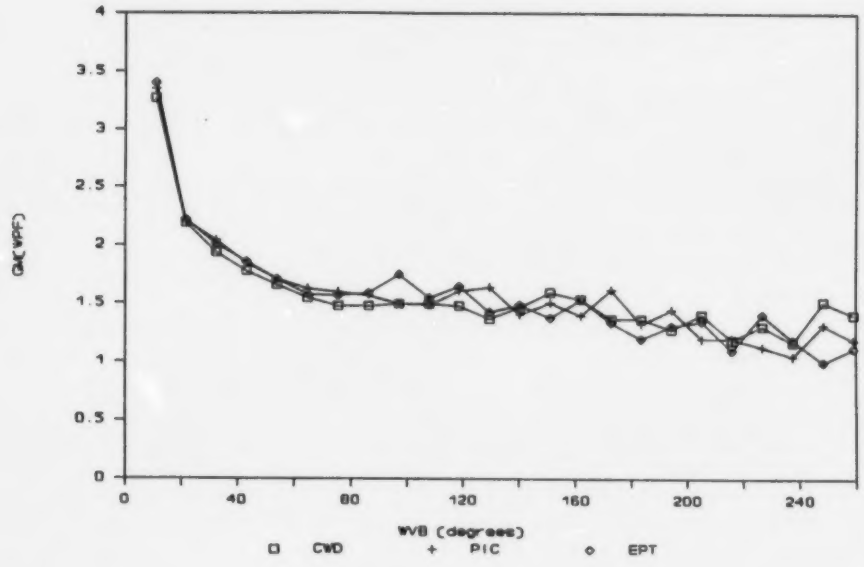
A possible explanation for these trends may be as follows. Recall that the value of TASR refers to the reference hour and that the plotted WVB and WPF refer to a period between 1 and 5 h after the reference hour. The maxima in the WVB may be associated with cases where the 4-h projection period includes sunrise or sunset, where conditions in the atmospheric boundary layer would be more likely to change. The minima in WVB in the hours after sunrise and in the hours following sunset may reflect a tendency for steady conditions to be established during the night or day.

WVB Versus Time After Sunrise (TASR) and Wind Speed

As wind meander is known to increase with decreasing wind speed, it was decided to separate the plots of WVB into three categories of wind speed, $u < 2$ m s^{-1}, $2 \leq u \leq 5$ m s^{-1} and $u > 5$ m s^{-1}, corresponding to low, moderate and high wind speeds, respectively. Figure 7 shows the results for the three sites for 1988. Figure 8 shows results for 1989.

The WVB was observed to decrease with increasing wind speed for all sites, as expected, with GM values typically between 10° and 15° for high wind speeds, 20° to 30° for moderate wind speeds and 30° to 60° for low wind speeds.

(a)



(b)

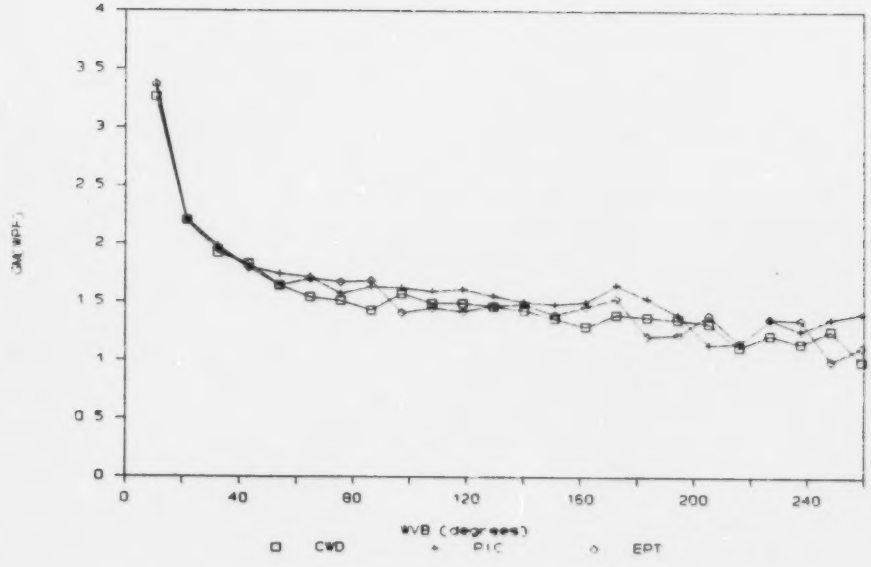
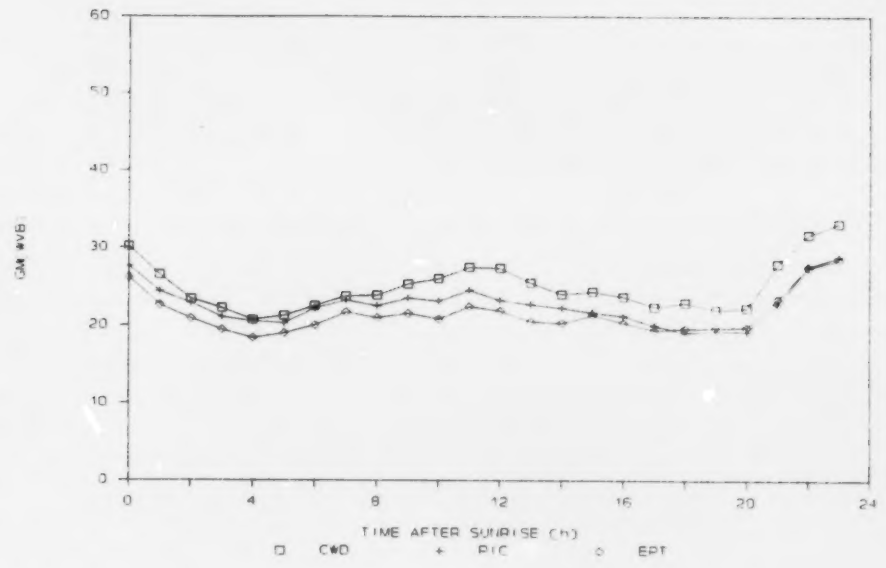


Figure 4. Geometric Mean (GM) of Wind Persistence Factor (WPF) versus Wind Variation Band (WVB) for Cherrywood (CWD), Pickering (PIC), and East Point (EPT) sites: (a) Pickering Mesonet 1988 data; (b) Pickering Mesonet 1989 data.

(a)



(b)

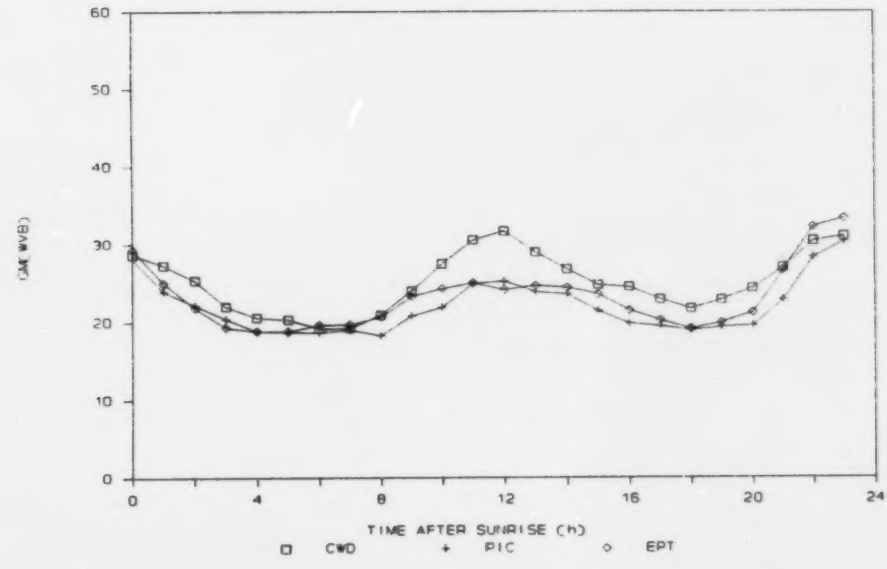
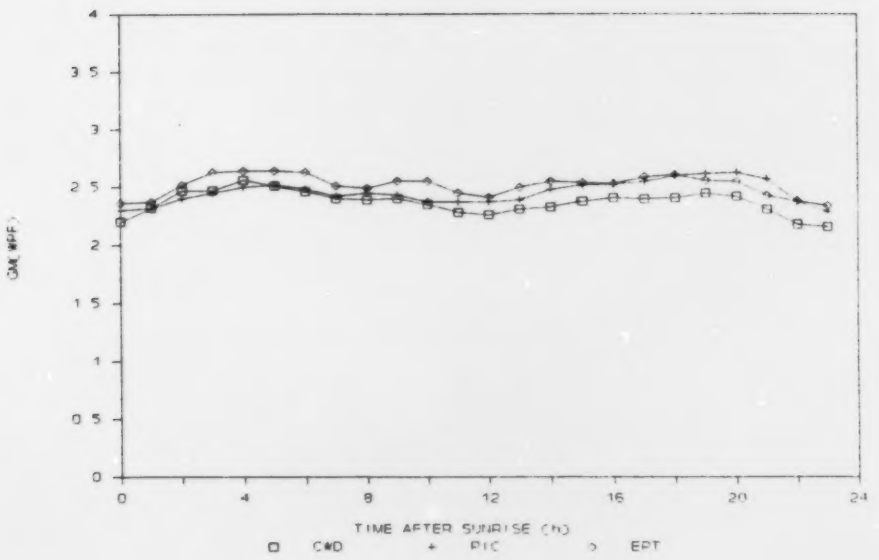


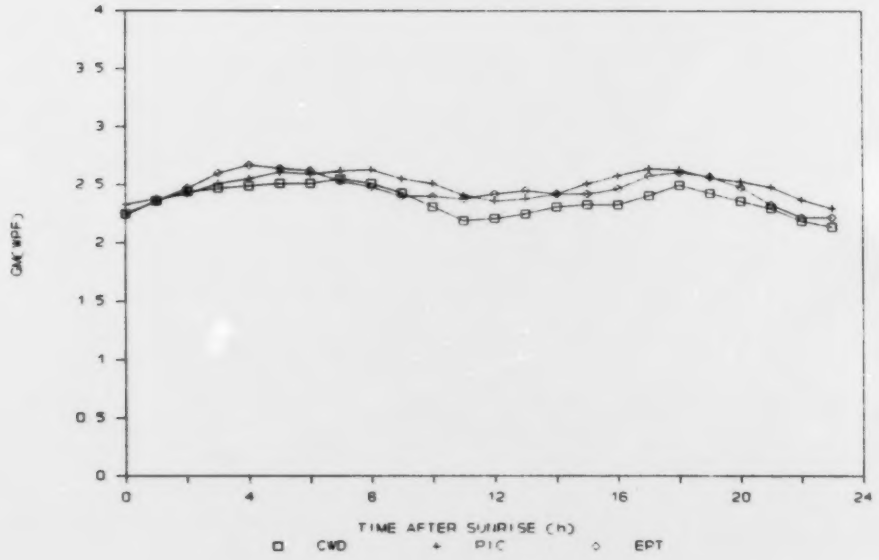
Figure 5. Geometric mean (GM) of Wind Variation Band (WVB) versus time after sunrise (TASR) for Cherrywood (CWD), Pickering (PIC), and East Point (EPT) sites: (a) Pickering Mesonet 1988 data; (b) Pickering Mesonet 1989 data.

(a)



WPSR

(b)



WPSR9

Figure 6. Geometric mean (GM) of Wind Persistence Factor (WPF) versus time after sunrise (TASR) for Cherrywood (CWD), Pickering (PIC), and East Point (EPT) sites: (a) Pickering Mesonet 1988 data; (b) Pickering Mesonet 1989 data.

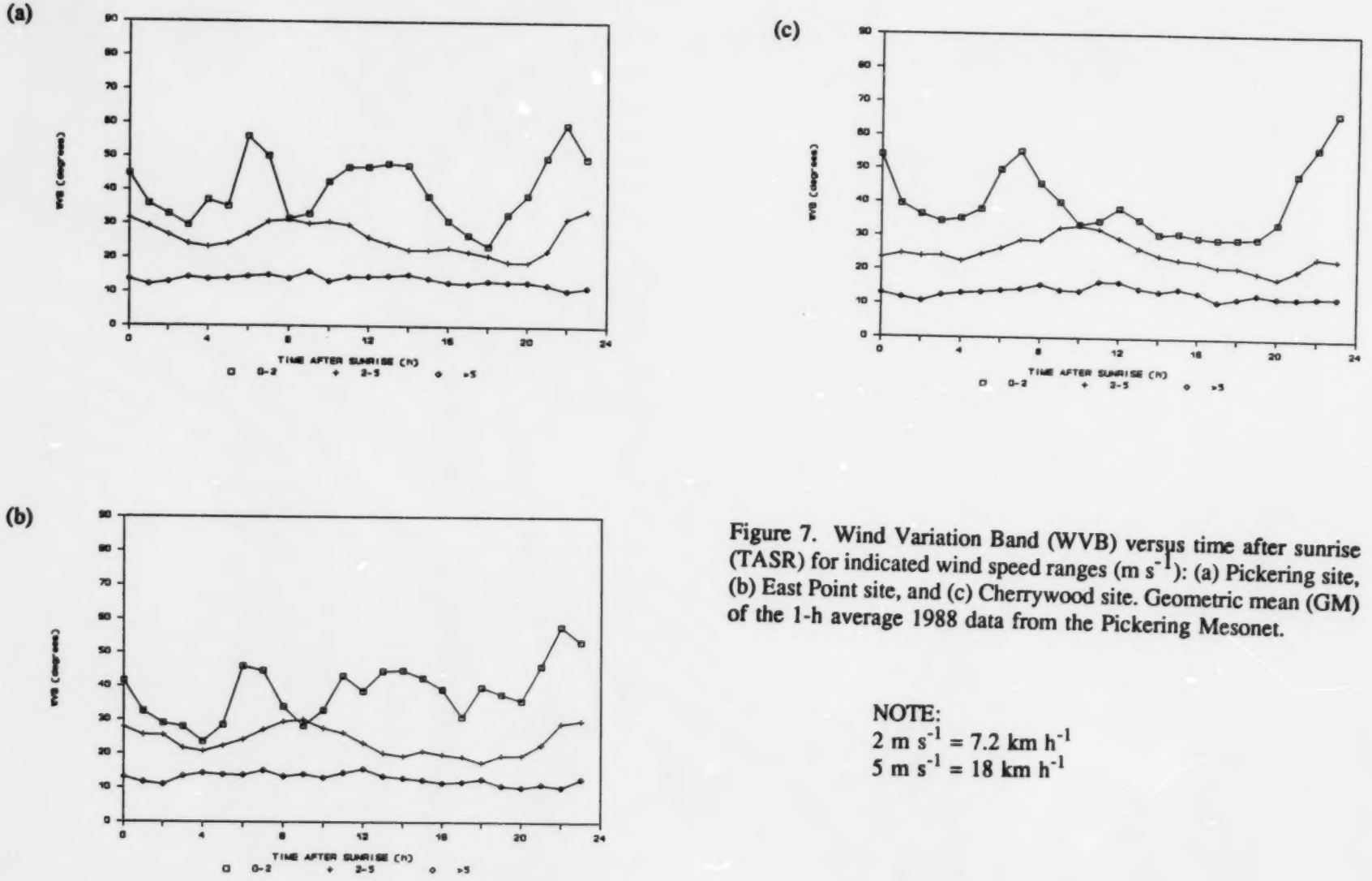


Figure 7. Wind Variation Band (WVB) versus time after sunrise (TASR) for indicated wind speed ranges (m s^{-1}): (a) Pickering site, (b) East Point site, and (c) Cherrywood site. Geometric mean (GM) of the 1-h average 1988 data from the Pickering Mesonet.

NOTE:
2 m s^{-1} = 7.2 km h^{-1}
5 m s^{-1} = 18 km h^{-1}

91-200

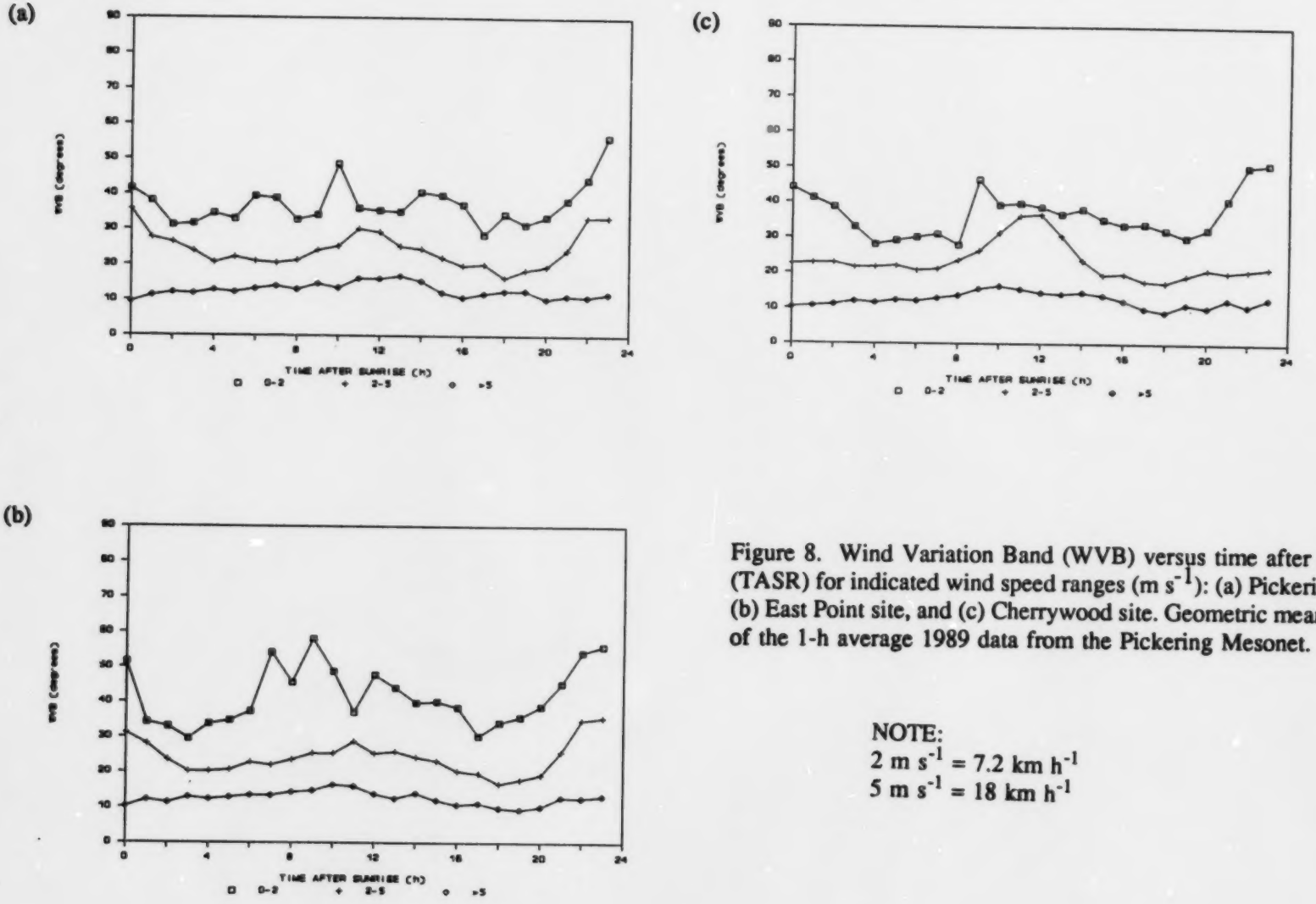


Figure 8. Wind Variation Band (WVB) versus time after sunrise (TASR) for indicated wind speed ranges (m s^{-1}): (a) Pickering site, (b) East Point site, and (c) Cherrywood site. Geometric mean (GM) of the 1-h average 1989 data from the Pickering Mesonet.

NOTE:
2 m s^{-1} = 7.2 km h^{-1}
5 m s^{-1} = 18 km h^{-1}

91-200

At high winds, no diurnal cycle was apparent in the WVB. However, as wind speed decreased, a cycle similar to that observed for the WVB averaged over all wind speeds (Figure 5) was increasingly apparent. At moderate wind speeds, the late afternoon/early evening maximum in the WVB occurred earlier at the lakeshore sites than at the Cherrywood site inland. At low wind speeds, a second peak in the WVB occurred at (a reference hour of) about 15 h. This second peak was not observed at the inland site. It is speculated that this may reflect wind direction shift due to land breezes being established at night at the lakeshore sites.

Values of the GSD ranged between about 2 and 3 at all sites and decreased with increasing wind speed. These values indicate significant variability in the WVB.

The WPF (not plotted) increased with wind speed at all sites with values typically 2 or less at low wind speed , between 2 and 2.5 at moderate wind speeds and about 3 at high wind speeds. The GSD was typically 1.5, with values increasing slightly with decreasing wind speed.

WVB Versus Time After Sunrise (TASR) and Synoptic Category

Figure 9 shows the GM of the WVB (1998 data only) classified by synoptic category for the Pickering, East Point and Cherrywood sites.

The figures show distinct differences in the patterns of WVB with synoptic category. Category 5, corresponding to high pressure systems with light winds shows the greatest variations with time of day and also exhibits the highest values near sunrise and sunset. These peaks in the WVB may reflect the establishment of land and lake breezes during and immediately after these transition periods. The lowest values of the WVB are usually associated with synoptic category 3, the region behind a cold front which may be associated with higher and more persistent winds.

The GM of the wind speed and the GM of the wind direction were plotted against the magnitude of the surface pressure gradient and the orientation of surface isobars, respectively, Figures 10 and 11. The correlation was as expected, with wind speed decreasing with decreasing pressure gradient and wind direction following, in general, the orientation of the surface isobars.

Standard Deviation of Wind Direction, σ_θ

The standard deviation of wind direction, σ_θ, is an important parameter as it will control the lateral spread of a release plume. The Mesonet data for 1988 were used to generate a plot of the GM of 1-h average σ_θ versus wind speed for each of the three sites considered, Figure 12. The GM of σ_θ for East Point varied little with wind speed and was about 10° (0.18 radians). The trend in σ_θ for Cherrywood was similar with a slightly higher GM which was typically ~12.5° (0.22 radians). At low wind speeds, σ_θ was observed to decrease, possibly an effect of anemometer wind response threshold. The scatter in σ_θ decreased with increasing wind speed. The Pickering site exhibited a different trend, showing that σ_θ decreased with increasing wind speed from a value of about 15° at low wind speed to about 7° at high wind speed.

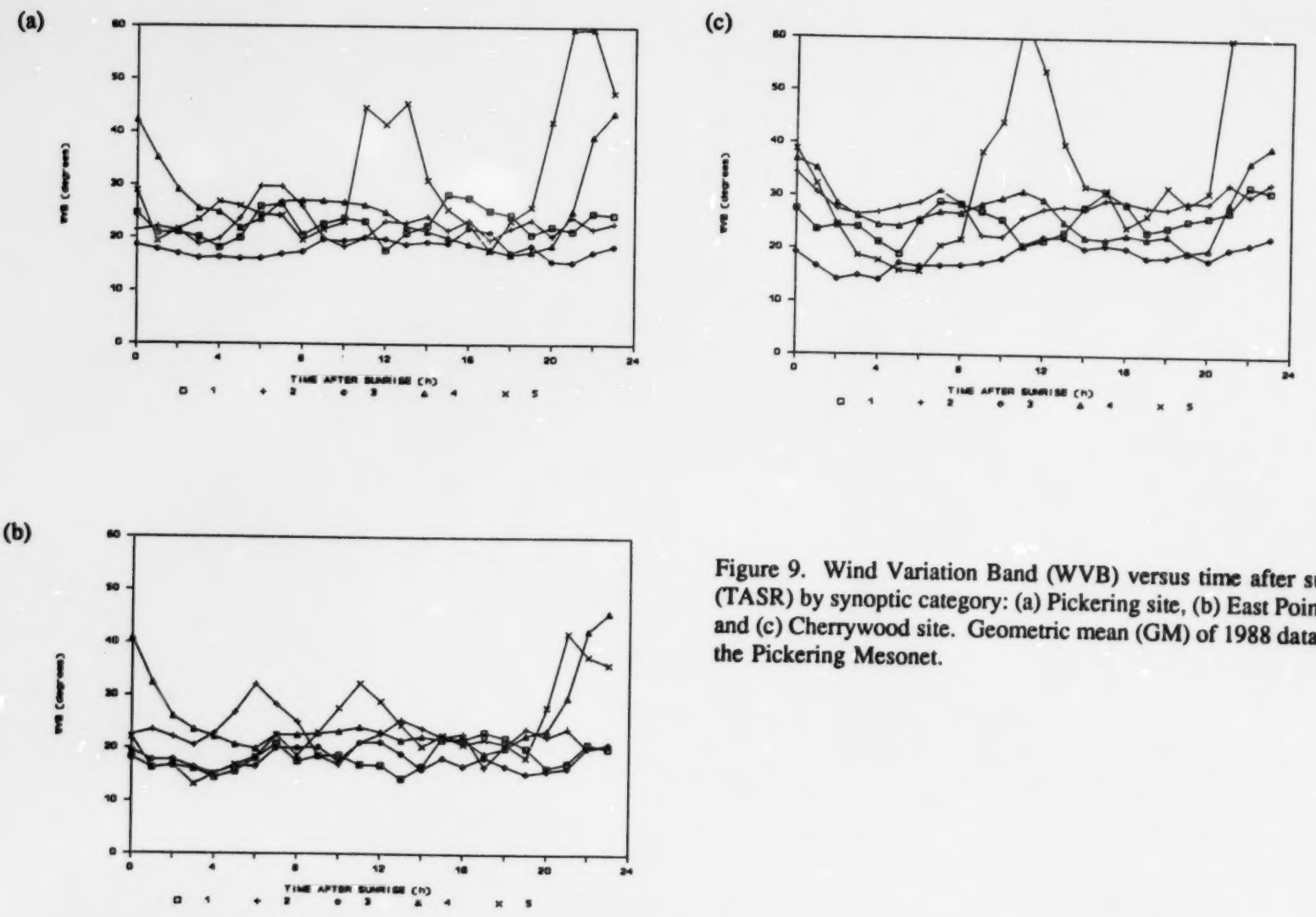


Figure 9. Wind Variation Band (WVB) versus time after sunrise (TASR) by synoptic category: (a) Pickering site, (b) East Point site, and (c) Cherrywood site. Geometric mean (GM) of 1988 data from the Pickering Mesonet.

91-200

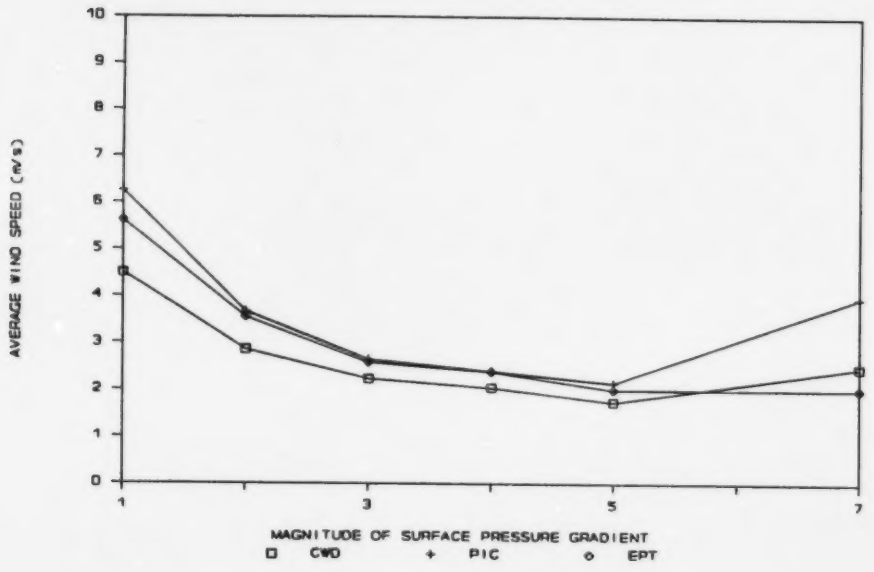


Figure 10. Geometric mean (GM) of wind speed for 1988 data from the Cherrywood (CWD), Pickering (PIC), and East Point (EPT) Mesonet sites versus magnitude of surface pressure gradient. (Categories as defined in Table 2 and determined from synoptic weather charts).

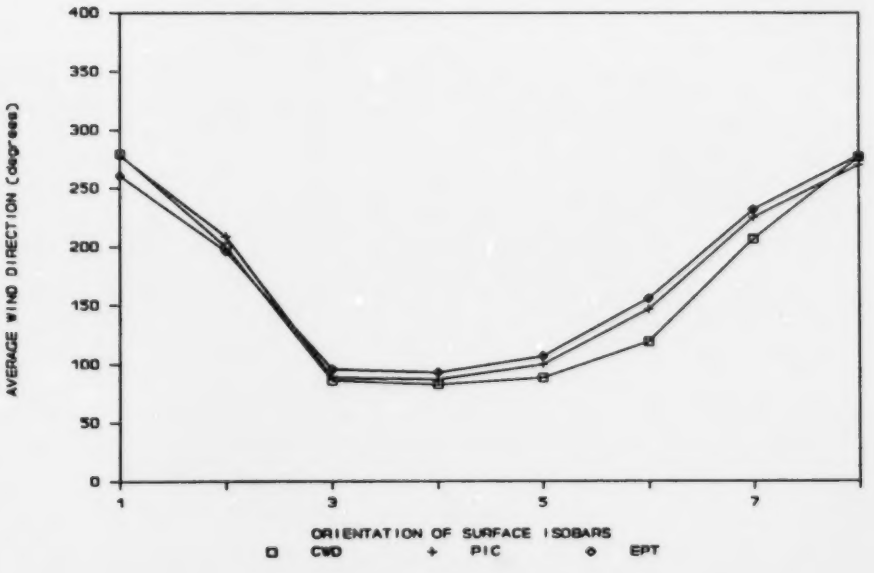
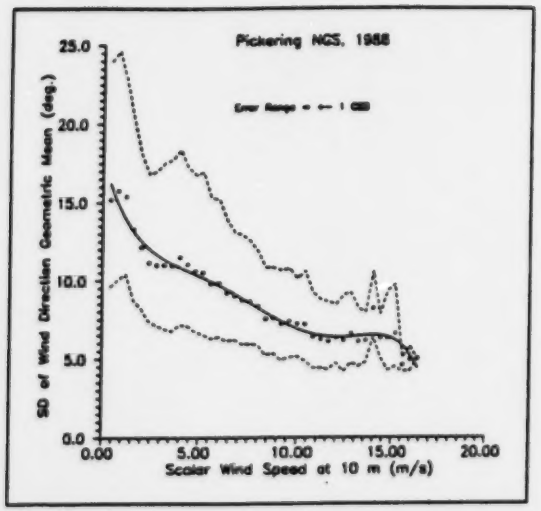
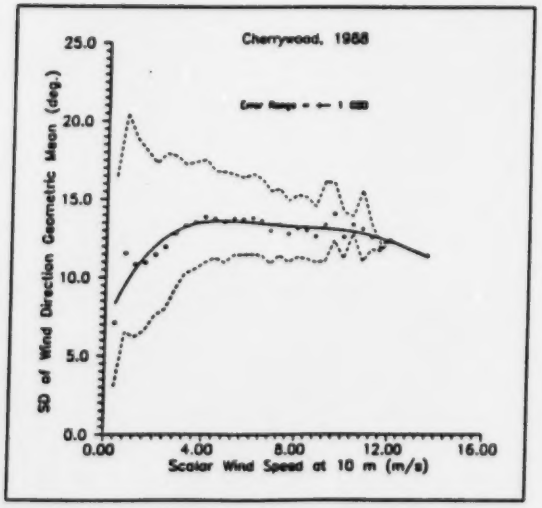


Figure 11. Geometric mean (GM) of wind direction for 1983 data from the Cherrywood (CWD), Pickering (PIC), and East Point (EPT) Mesonet sites versus orientation of surface isobars. (Categories as defined in Table 2 and determined from synoptic weather charts).

(a)



(c)



(b)

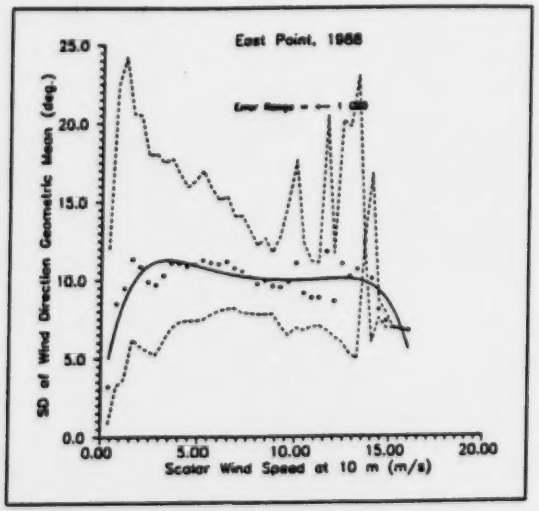


Figure 12. Standard deviation of wind direction, σ_θ, versus wind speed for (a) Pickering site, (b) East Point site, and (c) Cherrywood site. Geometric mean (GM) and geometric standard deviation (GSD) for all 1988 data (1-h average) from the Pickering Mesonet.

These results may provide useful default values of σ_θ when data from onsite towers are missing and also suggest that the traditional picture of an extremely narrow plume at low wind speed under stable conditions may not apply at some of these sites, a preliminary conclusion also reached from tracer studies of atmospheric dispersion at Darlington NGS (Ogram et al. 1989).

3.0 DISCUSSION

We consider briefly how the above results can be applied to assist meteorologists in the event of an emergency. Recall that the intent of the PVB, as originally defined, is to account for uncertainties in the average wind direction predicted for the *projection period*. It is suggested that the WVB, as defined above, be used in place of the PVB to meet this need. The specific values of WVB calculated above using the Mesonet data can be used as a guide in estimating typical values of the WVB for the Pickering site. As pointed out earlier, the WVB quantifies the variation in the 1-h average wind direction and bounds the 4-h average wind direction.

The WVB thus represents an uncertainty band centred on the predicted mean wind direction for the four hour period. A conservative approach to estimating the WVB is to use the average value of the WVB determined from historical data as a lower limit for the WVB. (Typical values of the WVB are much greater than the potential systematic error in wind direction measurement, hence sources of uncertainty due to the latter can for practical purposes be ignored). Typical values of the WVB derived from the Pickering Mesonet are summarized in Table 4. It is emphasized that Table 4 should only be used as a guide to likely values of the WVB under various conditions. Because of the degree of variation of the WVB within a given wind speed band or synoptic category, prediction of the WVB must ultimately rely on the experienced judgement of the meteorologist.

TABLE 4

WVB Range for Pickering for Various Wind Speed Ranges

Wind Speed ($m\ s^{-1}$) ($km\ h^{-1}$)	≤ 2 ≤ 7.2	2 to 5 7.2 to 18	> 5 > 18
WVB Range	35° to 45°	20° to 30°	10 to 15°

NOTE: The higher values of the WVB given for wind speeds < 5 m s^{-1} are usually associated with sunrise or sunset, and synoptic categories 4 and 5 (see Table 2).

Wind persistence factors (WPFs) were also calculated but it is concluded that this parameter may not be the best way of providing a correction factor to reduce the one-hour average plume centreline concentration, as calculated by the model, to a value appropriate for time averaging over the 4-h projection period. The reason for this is the apparently arbitrarily chosen criterion of 10°. The angular sector encompassed by the predicted plume width may be larger or smaller than 10°, thus a 10° variability may or may not have a significant effect depending on whether the predicted plume width (which is related to the 1-h average σ_θ) is larger or smaller than 10°. A better, and less arbitrary approach, may be to develop a statistical relationship between the 1-h

average σ_θ, which is measured, and the 4-h average value of σ_θ. The latter can then be input to the model instead of the 1-h average value.

Based on the above discussion the following recommendations are made:

(1) The usefulness of the WVB for setting lower limits on the uncertainty in projected wind direction should be tested in exercises involving meteorologists and real-time meteorological conditions.

(2) If these tests give promising results, data on WVB could be established from Ontario Hydro's other NGS sites using historical records from the on-site meteorological towers.

(3) Relationships between 1-h average σ_θ and 4-h average σ_θ should be derived from historical records to allow plume concentrations to be corrected for longer averaging times. This correction factor would take the place of the PPF (or WPF).

4.0 CONCLUDING REMARKS

Historical meterological data obtained from a network of meteorological towers located in the region surrounding Pickering NGS were analyzed to determine information on trends in local meteorological conditions for the purpose of aiding meteorologists in predicting future wind directions in the event of a nuclear emergency. The analysis identified problems with operational use of the Plume Persistence Factor (PPF) and Plume Variation Band (PVB) proposed by the Ontario Ministry of the Solicitor General to deal with uncertainty in projected wind direction during the four hour projection period (which covers the duration from one to five hours in the future). Revised definitions of the PPF and the PVB, termed the Wind Persistence Factor (WPF) and the Wind Variation Band (WVB), were therefore suggested.

Analysis of data from the Pickering Mesonet for the years 1988 and 1989 identified useful trends in the WVB and the WPF with wind speed, time after sunrise and synoptic category, and provided quantitative estimates of WVB and WPF under various conditions.

It is concluded that the WVB provides reasonable bounds on the uncertainty in average wind direction during the four-hour projection period. The results derived in this report for Pickering can be used to assist meteorologists in predicting the WVB in the event of an emergency.

The WPF (and PPF) are considered to be of limited use for the purpose of correcting 1-h average plume concentrations, which are predicted by the atmospheric dispersion model, to values

appropriate for the 4-h plume projection period. An alternative approach of directly inputting a 4-h average σ_θ to the model is suggested. Statistical relationships between 1-h average σ_θ and 4-h average σ_θ could be obtained from the analysis of historical data at NGS sites.

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APPENDIX A

Wind Variation Band (WVB) and Wind Persistence Factor (WPF) Derived from the Pickering Mesonet Data for 1988 and 1989
(GM - Geometric Mean, GSD - Geometric Standard Deviation)

1 CHERRYWOOD		1988
WPF vs WVB	GM	GSD
10.8	3.3	1.3
21.6	2.2	1.3
32.4	1.9	1.4
43.2	1.8	1.4
54.0	1.7	1.5
64.8	1.6	1.5
75.6	1.5	1.5
86.4	1.5	1.5
97.2	1.5	1.5
108.0	1.5	1.5
118.8	1.5	1.5
129.6	1.4	1.5
140.4	1.5	1.5
151.2	1.6	1.4
162.0	1.5	1.5
172.8	1.4	1.5
183.6	1.4	1.4
194.4	1.3	1.4
205.2	1.4	1.4
216.0	1.2	1.4
226.8	1.3	1.4
237.6	1.2	1.4
248.4	1.5	1.5
259.2	1.4	1.5
270.0	1.0	1.0
280.8	1.0	1.0
291.6	1.2	1.4
302.4	1.0	1.0
313.2	1.0	1.0
324.0	1.0	1.0
334.8	1.0	1.0

1 CHERRYWOOD	1988	
WVB vs TASR	GM	GSD
0	2.2	1.6
1	2.3	1.6
2	2.5	1.5
3	2.5	1.5
4	2.6	1.5
5	2.5	1.5
6	2.5	1.5
7	2.4	1.6
8	2.4	1.5
9	2.4	1.5
10	2.4	1.6
11	2.3	1.6
12	2.3	1.6
13	2.3	1.6
14	2.3	1.6
15	2.4	1.6
16	2.4	1.6
17	2.4	1.6
18	2.4	1.6
19	2.5	1.6
20	2.4	1.6
21	2.3	1.6
22	2.2	1.6
23	2.2	1.6

1 CHERRYWOOD 1988

WVB vs TASR	GM	GSD
0	30.2	2.7
1	26.6	2.7
2	23.5	2.7
3	22.3	2.6
4	20.8	2.6
5	21.3	2.6
6	22.6	2.7
7	23.8	2.8
8	24.0	2.9
9	25.4	2.9
10	26.1	2.8
11	27.6	3.1
12	27.5	2.7
13	25.6	2.5
14	24.2	2.6
15	24.5	2.6
16	23.8	2.6
17	22.5	2.7
18	23.1	2.6
19	22.1	2.6
20	22.4	2.7
21	28.0	2.8
22	31.8	2.8
23	33.3	2.9

1 CHERRYWOOD 1988

WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	1.8	1.5	2.4	1.6	2.9	1.5
1	2.1	1.5	2.3	1.6	3.1	1.4
2	2.1	1.6	2.5	1.5	3.2	1.3
3	2.1	1.6	2.4	1.5	3.0	1.4
4	2.2	1.5	2.5	1.5	2.9	1.4
5	2.0	1.6	2.4	1.5	3.0	1.4
6	1.8	1.5	2.3	1.5	3.0	1.4
7	1.7	1.6	2.2	1.6	2.9	1.4
8	1.8	1.6	2.2	1.5	2.9	1.4
9	1.9	1.6	2.3	1.5	2.8	1.5
10	2.1	1.6	2.2	1.5	2.9	1.4
11	2.1	1.6	2.2	1.6	2.8	1.5
12	2.1	1.6	2.2	1.6	2.8	1.4
13	2.1	1.6	2.3	1.6	2.9	1.4
14	2.1	1.6	2.3	1.6	2.9	1.5
15	2.1	1.6	2.5	1.5	2.9	1.4
16	2.2	1.6	2.5	1.5	3.0	1.4
17	2.1	1.6	2.5	1.5	3.3	1.4
18	2.1	1.6	2.6	1.5	3.2	1.3
19	2.1	1.7	2.6	1.5	3.1	1.3
20	2.1	1.6	2.6	1.5	3.2	1.4
21	1.9	1.6	2.6	1.5	3.2	1.3
22	1.8	1.5	2.4	1.5	3.0	1.5
23	1.7	1.5	2.4	1.5	3.1	1.5

1 CHERRYWOOD 1988
WVB vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	54.0	2.4	23.4	2.5	13.0	2.4
1	39.5	2.5	24.6	2.6	11.8	2.2
2	36.4	2.5	24.0	2.5	10.8	2.2
3	34.3	2.6	24.2	2.5	12.5	2.1
4	35.2	2.5	22.5	2.5	13.2	2.3
5	38.0	2.6	24.6	2.5	13.4	2.3
6	49.8	2.5	26.4	2.5	13.9	2.5
7	55.2	2.3	28.8	2.7	14.4	2.4
8	45.6	2.8	28.6	2.9	15.6	2.5
9	40.1	2.3	32.4	2.9	14.1	2.5
10	33.5	2.9	33.1	2.7	13.8	2.4
11	34.5	2.5	32.1	3.3	16.6	2.6
12	38.3	2.6	29.4	2.7	16.5	2.3
13	35.0	2.6	26.5	2.5	14.6	2.0
14	30.7	2.7	24.3	2.4	13.7	2.2
15	30.9	2.6	23.2	2.5	14.6	2.2
16	29.8	2.7	22.6	2.5	13.5	2.3
17	29.3	2.8	21.0	2.5	11.0	2.3
18	29.4	2.6	21.1	2.4	12.0	2.3
19	29.7	2.7	19.5	2.5	13.1	2.3
20	34.1	2.7	17.9	2.3	12.3	2.5
21	48.5	2.7	20.4	2.1	12.2	3.0
22	56.4	2.5	24.2	2.4	12.4	2.8
23	66.7	2.2	23.5	2.6	12.5	2.7

1 CHERRYWOOD 1988
WVB vs TASR by Synoptic Category (GM, GSD)

	1		2		3		4		5	
0	27.4	2.5	34.3	2.7	19.2	2.5	36.9	2.9	38.8	2.9
1	23.6	2.5	30.6	2.8	16.6	2.4	35.2	2.7	32.2	2.4
2	24.4	2.5	27.5	3.1	14.2	2.6	28.6	2.5	24.7	2.3
3	24.2	2.7	26.5	2.9	14.9	2.5	26.2	2.4	18.8	2.3
4	21.3	2.6	26.9	2.7	14.1	2.6	24.5	2.4	17.8	2.4
5	19.0	2.6	28.0	2.7	17.3	2.5	24.3	2.6	15.9	2.6
6	25.3	2.6	28.7	2.9	16.7	2.9	25.6	2.5	15.7	2.8
7	28.9	2.7	30.9	2.8	16.8	2.6	27.0	2.7	20.5	3.1
8	28.5	2.7	28.6	3.0	16.9	2.7	26.8	3.0	21.8	2.5
9	27.1	2.9	22.5	3.4	17.3	2.5	28.5	2.9	38.4	2.7
10	25.6	3.6	22.3	2.9	18.2	2.4	29.6	2.7	44.1	3.1
11	20.6	4.7	26.0	2.8	20.8	2.3	31.0	2.8	63.8	3.2
12	21.7	2.5	27.6	3.1	22.3	2.2	29.5	2.7	53.9	2.9
13	23.2	2.3	28.1	3.0	22.3	2.1	25.2	2.6	40.0	2.8
14	28.1	2.6	27.7	2.7	20.2	2.2	22.3	2.6	32.0	2.9
15	31.0	2.6	29.4	2.7	20.8	2.5	22.0	2.5	31.3	3.0
16	28.7	2.7	29.0	2.9	20.4	2.6	22.9	2.4	24.3	2.9
17	23.5	2.6	28.1	2.9	18.5	2.7	22.2	2.5	26.6	3.1
18	24.3	2.5	27.8	2.7	18.7	2.7	22.8	2.5	31.9	2.8
19	25.6	2.7	29.3	2.7	19.8	2.5	19.6	2.6	28.6	2.8
20	26.3	2.8	29.0	2.7	18.2	2.5	20.2	2.4	31.1	3.4
21	27.4	2.8	32.6	2.8	20.3	2.7	28.9	2.5	60.0	2.7
22	32.3	2.7	30.5	3.0	21.2	2.7	36.9	2.6	71.8	3.2
23	31.2	2.8	32.9	2.9	22.5	2.7	39.7	2.8	70.6	3.0

1 CHERRYWOOD 1988

SWS vs MPG	GM	GSD
1	4.5	1.6
2	2.9	1.8
3	2.2	1.8
4	2.1	1.7
5	1.8	1.8
7	2.5	1.1

SWS vs ORW	GM	GSD
1	279.2	2.0
2	200.3	3.0
3	86.0	4.0
4	82.8	2.4
5	88.3	2.6
6	119.1	3.0
7	207.0	2.1
8	276.9	1.6

2 PICKERING NGS 1988

WPF vs WVB	GM	GSD
10.8	3.4	1.3
21.6	2.2	1.3
32.4	2.0	1.4
43.2	1.9	1.4
54.0	1.7	1.5
64.8	1.6	1.5
75.6	1.6	1.5
86.4	1.6	1.5
97.2	1.5	1.5
108.0	1.5	1.5
118.8	1.6	1.5
129.6	1.6	1.5
140.4	1.4	1.4
151.2	1.5	1.5
162.0	1.4	1.5
172.8	1.6	1.5
183.6	1.3	1.4
194.4	1.5	1.4
205.2	1.2	1.4
216.0	1.2	1.4
226.8	1.1	1.3
237.6	1.1	1.2
248.4	1.3	1.5
259.2	1.2	1.4
270.0	1.2	1.4
280.8	1.0	0.0
291.6	1.3	1.5
302.4	1.0	0.0
324.0	1.4	1.6
334.8	2.0	0.0

2 PICKERING NGS 1988

WPF vs TASR	GM	GSD
0	2.3	1.6
1	2.3	1.6
2	2.4	1.6
3	2.5	1.5
4	2.5	1.5
5	2.5	1.5
6	2.5	1.5
7	2.4	1.6
8	2.5	1.6
9	2.4	1.6
10	2.4	1.6
11	2.4	1.6
12	2.4	1.6
13	2.4	1.6
14	2.5	1.5
15	2.5	1.5
16	2.5	1.5
17	2.6	1.5
18	2.6	1.5
19	2.6	1.5
20	2.6	1.5
21	2.6	1.5
22	2.4	1.6
23	2.3	1.6

2 PICKERING NGS 1988

WVB vs TASR	GM	GSD
0	27.6	3.3
1	24.5	3.1
2	22.9	3.0
3	21.2	2.8
4	20.6	2.7
5	20.4	3.1
6	22.3	3.0
7	23.3	2.9
8	22.6	3.0
9	23.6	3.1
10	23.2	3.0
11	24.6	2.9
12	23.3	2.9
13	22.8	2.8
14	22.4	3.0
15	21.8	2.8
16	21.3	2.9
17	20.0	3.0
18	19.2	2.9
19	19.4	2.9
20	19.3	3.0
21	22.9	3.1
22	27.7	3.3
23	29.0	3.5

2 PICKERING NGS 1988

WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	2.0	1.5	2.2	1.6	2.9	1.5
1	2.1	1.6	2.2	1.6	2.9	1.5
2	2.2	1.5	2.2	1.6	3.0	1.4
3	2.1	1.6	2.4	1.5	2.8	1.4
4	2.0	1.5	2.5	1.6	2.8	1.5
5	2.3	1.6	2.3	1.5	2.9	1.4
6	2.0	1.4	2.3	1.5	2.8	1.5
7	1.7	1.6	2.3	1.5	2.8	1.5
8	2.2	1.7	2.2	1.6	2.9	1.5
9	2.2	1.7	2.2	1.5	2.8	1.5
10	1.8	1.7	2.1	1.6	3.0	1.4
11	1.8	1.6	2.2	1.6	2.9	1.4
12	1.9	1.6	2.2	1.6	2.9	1.4
13	2.1	1.6	2.3	1.6	2.8	1.4
14	2.1	1.6	2.4	1.6	2.8	1.5
15	2.1	1.5	2.5	1.5	2.9	1.5
16	2.1	1.6	2.5	1.5	3.1	1.4
17	2.4	1.6	2.5	1.5	2.9	1.5
18	2.4	1.6	2.5	1.5	3.0	1.5
19	2.3	1.5	2.6	1.5	3.0	1.5
20	2.1	1.5	2.7	1.5	3.0	1.4
21	2.1	1.5	2.6	1.5	3.1	1.4
22	1.9	1.6	2.3	1.5	3.1	1.5
23	1.9	1.6	2.2	1.6	3.0	1.5

2 PICKERING NGS 1988
WVB vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	44.9	2.6	31.6	3.4	13.6	2.7
1	36.0	2.9	29.3	3.0	12.1	2.8
2	32.9	2.5	26.7	2.9	12.9	2.8
3	29.6	2.8	24.0	2.8	14.2	2.6
4	37.1	2.4	23.1	2.7	13.6	2.6
5	35.3	2.6	24.1	3.1	13.9	2.8
6	56.0	2.2	27.0	2.7	14.5	2.9
7	50.3	2.3	30.7	2.5	14.9	3.1
8	31.6	2.9	31.3	2.7	13.9	3.0
9	33.1	3.3	30.1	2.9	15.9	2.9
10	42.7	2.8	30.7	2.7	13.2	2.7
11	47.0	2.3	29.7	2.8	14.4	2.6
12	47.0	3.0	26.0	2.8	14.5	2.6
13	48.0	2.9	24.1	2.7	14.7	2.5
14	47.5	3.1	22.5	2.8	15.2	2.9
15	38.4	2.8	22.4	2.6	14.0	2.8
16	31.1	3.0	23.0	2.6	12.8	3.0
17	26.8	3.0	21.9	2.6	12.6	3.5
18	23.6	3.0	20.8	2.6	13.3	3.2
19	33.0	3.2	19.0	2.6	13.1	2.8
20	38.7	2.4	18.9	3.0	13.1	2.9
21	50.0	2.8	22.3	2.8	12.3	2.8
22	59.7	2.4	31.9	2.9	10.7	2.9
23	49.8	2.8	34.3	3.3	11.7	2.9

1 PICKERING 1988
WVB vs TASR by Synoptic Category (GM, GSD)

	1		2		3		4		5	
0	24.6	2.5	21.4	3.5	18.6	3.1	42.2	3.3	28.9	3.4
1	20.9	2.7	22.1	3.8	17.8	2.8	35.1	3.1	19.3	2.8
2	21.0	2.7	21.4	4.1	17.0	2.8	29.1	2.8	21.6	2.5
3	20.1	2.7	18.7	3.5	16.1	2.6	25.5	2.7	23.5	2.6
4	18.1	2.6	19.8	3.8	16.3	2.6	24.9	2.6	26.9	2.8
5	20.0	2.8	23.7	3.4	16.0	2.8	21.9	3.3	26.1	3.3
6	26.0	3.0	29.8	3.4	16.1	2.9	23.6	2.7	24.5	3.4
7	26.5	3.0	29.7	3.6	16.9	2.9	26.9	2.6	24.3	3.1
8	20.6	3.1	26.0	3.6	17.4	2.8	27.1	2.8	19.6	3.3
9	22.7	3.6	20.1	3.4	19.7	2.6	27.1	3.1	21.7	2.8
10	23.8	3.5	18.4	3.2	19.5	2.5	26.8	2.9	23.1	2.6
11	23.2	3.2	20.0	3.1	20.2	2.4	26.3	2.9	44.6	2.9
12	17.7	2.7	23.2	3.6	19.8	2.2	25.0	3.1	41.5	3.4
13	21.0	2.4	23.0	3.2	18.9	2.4	22.4	2.9	45.5	3.1
14	22.4	2.9	24.1	4.2	19.3	2.4	21.3	2.8	31.0	4.1
15	28.3	2.8	21.5	4.0	19.1	2.6	20.2	2.5	25.5	3.3
16	27.7	3.0	23.4	4.1	22.0	2.5	19.0	2.7	22.7	3.3
17	25.2	3.1	19.8	4.1	21.2	2.7	17.9	2.7	17.6	2.8
18	24.5	3.3	21.9	3.2	17.3	2.8	16.9	2.6	23.3	3.3
19	20.7	3.2	23.5	3.3	18.6	2.6	17.5	2.7	26.0	3.4
20	22.3	2.8	20.5	3.4	15.7	2.8	18.7	2.9	42.1	3.5
21	21.4	2.9	24.0	4.0	15.5	2.5	25.2	2.9	59.5	2.8
22	24.9	2.9	21.8	4.3	17.4	3.0	39.2	2.8	59.5	3.5
23	24.5	2.9	22.9	4.1	18.6	3.1	43.8	3.1	47.6	3.7

2 PICKERING NGS 1988

SWS vs MPG	GM	GSD
1	6.3	1.6
2	3.7	1.6
3	2.7	1.6
4	2.4	1.6
5	2.2	1.5
7	4.0	1.1

WD vs ORW	GM	GSD
1	278.2	1.7
2	208.9	3.1
3	88.9	4.5
4	87.3	2.8
5	99.7	3.0
6	146.8	2.2
7	225.2	1.8
8	270.2	1.8

5 EAST POINT 1988

WPF vs WVB	GM	GSD
10.8	3.4	1.3
21.6	2.2	1.3
32.4	2.0	1.4
43.2	1.9	1.4
54.0	1.7	1.5
64.8	1.6	1.5
75.6	1.6	1.5
86.4	1.6	1.5
97.2	1.8	1.4
108.0	1.6	1.5
118.8	1.7	1.5
129.6	1.4	1.4
140.4	1.5	1.5
151.2	1.4	1.4
162.0	1.5	1.5
172.8	1.3	1.5
183.6	1.2	1.4
194.4	1.3	1.4
205.2	1.4	1.4
216.0	1.1	1.3
226.8	1.4	1.4
237.6	1.2	1.4
248.4	1.0	1.0
259.2	1.1	1.3
270.0	1.0	1.0
280.8	1.0	1.0
291.6	1.0	1.0
302.4	1.3	1.5
313.2	2.0	0.0
324.0	1.0	1.0
334.8	1.3	1.5

5 EAST POINT 1988

WPF vs TASR	GM	GSD
0	2.4	1.6
1	2.4	1.6
2	2.5	1.5
3	2.6	1.5
4	2.6	1.5
5	2.6	1.5
6	2.6	1.5
7	2.5	1.5
8	2.5	1.5
9	2.6	1.5
10	2.6	1.5
11	2.5	1.6
12	2.4	1.6
13	2.5	1.6
14	2.6	1.6
15	2.5	1.6
16	2.5	1.6
17	2.6	1.6
18	2.6	1.5
19	2.6	1.6
20	2.6	1.6
21	2.4	1.6
22	2.4	1.6
23	2.3	1.6

5 EAST POINT 1988
WVB vs TASR

	GM	GSD
0	26.2	3.1
1	22.7	3.0
2	20.9	2.9
3	19.5	2.9
4	18.4	2.8
5	19.1	2.9
6	20.1	2.8
7	21.8	2.7
8	21.1	3.0
9	21.7	3.1
10	20.9	3.1
11	22.5	3.0
12	22.0	2.8
13	20.6	3.1
14	20.4	3.1
15	21.4	3.1
16	20.4	3.0
17	19.5	2.9
18	19.7	2.9
19	19.8	3.1
20	19.8	3.0
21	23.5	3.3
22	27.6	3.4
23	28.7	3.4

5 EAST POINT 1988
WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	2.1	1.6	2.3	1.6	3.1	1.4
1	2.2	1.6	2.2	1.6	3.0	1.5
2	2.2	1.5	2.4	1.5	3.1	1.4
3	2.3	1.5	2.5	1.5	3.0	1.4
4	2.4	1.5	2.6	1.5	2.9	1.5
5	2.3	1.5	2.5	1.5	3.0	1.4
6	2.1	1.5	2.4	1.5	3.0	1.4
7	2.0	1.6	2.3	1.5	2.9	1.5
8	2.2	1.5	2.2	1.6	2.9	1.4
9	2.2	1.6	2.3	1.6	3.0	1.4
10	2.2	1.7	2.3	1.5	3.0	1.4
11	1.9	1.6	2.4	1.6	2.9	1.5
12	1.9	1.7	2.4	1.5	2.8	1.5
13	1.8	1.7	2.6	1.5	2.8	1.5
14	1.9	1.6	2.6	1.5	3.0	1.5
15	1.9	1.6	2.6	1.5	3.1	1.4
16	2.0	1.6	2.5	1.5	3.2	1.4
17	2.2	1.7	2.6	1.5	3.1	1.4
18	2.0	1.6	2.7	1.5	3.1	1.3
19	2.0	1.6	2.6	1.5	3.2	1.4
20	2.1	1.5	2.6	1.6	3.2	1.4
21	2.0	1.6	2.4	1.6	3.1	1.4
22	1.9	1.5	2.3	1.6	3.3	1.3
23	2.0	1.6	2.2	1.6	3.2	1.4

5 EAST POINT 1988
WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	41.6	3.1	27.8	2.9	13.0	2.5
1	32.5	3.0	25.6	2.9	11.6	2.3
2	29.0	2.4	25.5	2.9	10.9	2.4
3	28.0	2.6	21.7	3.0	13.4	2.5
4	23.6	2.5	20.8	3.0	14.3	2.5
5	28.6	2.6	22.4	3.0	13.8	2.6
6	45.9	2.6	24.3	2.8	13.7	2.6
7	44.6	2.4	27.2	2.6	15.1	2.4
8	34.0	2.8	29.6	2.8	13.4	2.7
9	28.4	2.6	30.2	3.1	14.0	2.6
10	32.9	3.1	27.6	3.0	12.9	2.7
11	43.1	2.9	26.2	2.8	14.3	2.7
12	38.6	2.7	23.2	2.8	15.5	2.5
13	44.5	2.8	20.2	2.8	13.4	3.1
14	44.7	3.1	19.3	3.0	12.8	2.5
15	42.5	2.9	20.8	3.1	12.3	2.4
16	39.1	2.8	19.8	2.8	11.4	2.7
17	31.0	2.8	19.1	2.7	11.7	2.8
18	39.8	2.7	17.4	2.8	12.5	2.4
19	37.7	2.9	19.5	2.9	10.6	2.4
20	35.8	2.7	19.5	2.9	10.1	2.5
21	46.1	2.8	22.8	3.1	11.0	2.8
22	57.8	2.8	29.1	3.1	10.2	2.7
23	53.3	3.0	29.9	3.3	12.6	2.7

5 EAST POINT 1988
WVB vs TASR by Synoptic Category (GM, GSD)

	1		2		3		4		5	
0	18.3	3.0	22.5	3.1	19.6	2.8	40.9	2.8	22.0	3.2
1	16.2	2.9	23.5	3.1	17.8	2.6	32.3	2.8	16.3	3.5
2	16.8	2.9	22.1	3.1	17.8	2.7	26.0	2.8	16.8	2.3
3	16.1	3.0	20.6	3.0	16.4	2.8	23.5	2.9	13.2	2.2
4	14.5	2.7	22.9	3.3	15.2	2.6	22.2	2.7	15.2	2.7
5	15.6	2.7	26.8	3.0	16.7	2.7	20.7	2.8	16.9	3.5
6	18.2	2.7	32.1	3.1	16.7	2.6	20.0	2.8	18.4	3.8
7	20.9	2.4	28.3	3.3	20.1	2.5	22.7	2.7	22.6	2.9
8	17.6	2.9	25.0	3.8	20.1	2.5	22.6	3.0	18.7	3.5
9	18.6	3.1	18.7	3.8	20.3	2.5	22.9	3.1	23.0	3.5
10	18.8	3.4	17.0	3.4	17.7	2.4	23.3	3.1	27.6	3.6
11	16.9	3.6	21.2	2.8	21.1	2.3	24.0	3.0	32.3	4.2
12	16.8	2.9	22.7	2.6	21.2	2.0	23.1	3.0	29.0	3.7
13	14.3	4.8	25.5	3.0	19.0	2.4	21.6	2.8	24.4	4.3
14	16.7	3.2	23.9	4.0	16.1	2.7	22.3	2.7	20.4	4.7
15	22.2	3.4	22.2	4.5	18.2	2.9	21.7	2.7	22.5	4.0
16	21.8	3.4	22.8	4.3	16.7	2.8	21.7	2.6	20.8	3.2
17	23.1	3.4	16.5	3.6	18.3	2.6	19.1	2.7	21.8	3.0
18	22.1	3.4	20.6	2.9	16.7	2.7	20.2	2.9	20.9	3.4
19	20.1	3.2	23.8	2.8	15.3	2.9	22.6	2.9	18.4	4.7
20	16.4	3.2	22.3	2.7	15.8	2.8	23.5	3.0	27.9	3.2
21	17.4	3.2	23.8	3.8	16.5	2.7	29.7	3.2	41.9	3.3
22	21.0	3.3	20.1	3.8	20.3	3.0	42.4	3.1	37.6	3.8
23	20.2	3.3	20.8	3.6	20.9	3.0	45.8	3.2	36.0	3.2

5 EAST POINT 1988

SWS vs MPG	GM	GSD
1	5.6	1.6
2	3.6	1.7
3	2.6	1.7
4	2.4	1.7
5	2.0	1.8
7	2.0	1.3

WD vs ORW	GM	GSD
1	260.6	2.1
2	196.4	3.0
3	95.7	3.5
4	92.9	2.3
5	106.8	2.3
6	156.0	2.2
7	231.8	1.6
8	278.3	1.5

1 CHERRYWOOD 1989

WPF vs WVB	GM	GSD
10.8	3.3	1.3
21.6	2.2	1.3
32.4	1.9	1.4
43.2	1.8	1.4
54.0	1.6	1.5
64.8	1.5	1.5
75.6	1.5	1.5
86.4	1.4	1.5
97.2	1.6	1.5
108.0	1.5	1.5
118.8	1.5	1.5
129.6	1.5	1.5
140.4	1.4	1.5
151.2	1.4	1.5
162.0	1.3	1.4
172.8	1.4	1.5
183.6	1.4	1.5
194.4	1.4	1.4
205.2	1.3	1.4
216.0	1.1	1.3
226.8	1.2	1.4
237.6	1.2	1.4
248.4	1.3	1.4
259.2	1.0	1.0
270.0	1.2	1.4
280.8	1.0	1.0
291.6	1.3	1.5
302.4	1.0	1.0
313.2	1.0	1.0
324.0	1.0	0.0
334.8	1.0	0.0

1 CHERRYWOOD 1989

WPF vs TASR	GM	GSD
0	2.3	1.6
1	2.4	1.5
2	2.4	1.5
3	2.5	1.6
4	2.5	1.6
5	2.5	1.5
6	2.5	1.5
7	2.6	1.5
8	2.5	1.5
9	2.4	1.5
10	2.3	1.6
11	2.2	1.6
12	2.2	1.6
13	2.3	1.6
14	2.3	1.6
15	2.3	1.6
16	2.3	1.6
17	2.4	1.6
18	2.5	1.6
19	2.4	1.6
20	2.4	1.6
21	2.3	1.6
22	2.2	1.6
23	2.1	1.6

1 CHERRYWOOD 1989

WVB vs TASR	GM	GSD
0	28.7	2.8
1	27.3	2.8
2	25.4	2.6
3	22.1	2.7
4	20.6	2.6
5	20.4	2.5
6	19.2	2.4
7	19.3	2.4
8	21.0	2.5
9	24.0	2.7
10	27.5	2.8
11	30.5	2.8
12	31.7	2.8
13	29.0	2.8
14	26.8	2.8
15	24.8	2.7
16	24.6	2.7
17	22.9	2.7
18	21.7	2.7
19	22.9	2.6
20	24.4	2.6
21	27.0	2.8
22	30.4	2.8
23	31.0	2.8

1 CHERRYWOOD 1989

WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	1.9	1.6	2.4	1.5	3.4	1.3
1	2.1	1.5	2.5	1.5	3.3	1.3
2	2.2	1.6	2.4	1.5	3.3	1.3
3	2.2	1.6	2.5	1.5	3.1	1.4
4	2.1	1.6	2.5	1.5	3.2	1.3
5	2.2	1.6	2.4	1.5	3.1	1.4
6	2.2	1.5	2.4	1.5	3.0	1.4
7	2.1	1.5	2.5	1.5	3.0	1.3
8	2.3	1.5	2.4	1.5	3.0	1.4
9	1.9	1.6	2.3	1.5	3.0	1.4
10	2.0	1.7	2.2	1.6	2.8	1.4
11	2.0	1.5	2.1	1.6	2.8	1.5
12	1.9	1.5	2.2	1.5	2.9	1.5
13	2.1	1.5	2.2	1.6	3.0	1.4
14	2.1	1.5	2.4	1.6	3.0	1.5
15	2.0	1.6	2.6	1.5	3.1	1.4
16	2.1	1.6	2.5	1.5	3.0	1.5
17	2.1	1.6	2.7	1.5	3.3	1.5
18	2.2	1.6	2.8	1.5	3.3	1.5
19	2.2	1.6	2.6	1.6	3.1	1.6
20	2.1	1.6	2.5	1.6	3.2	1.4
21	2.0	1.6	2.5	1.6	3.1	1.3
22	1.8	1.6	2.5	1.6	3.3	1.3
23	1.8	1.6	2.4	1.5	3.2	1.3

CHERRYWOOD 1989
WVB vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	44.1	2.6	22.5	2.5	10.3	2.2
1	41.2	2.6	22.9	2.5	10.7	2.3
2	38.7	2.5	23.0	2.4	11.2	2.0
3	33.1	2.7	21.7	2.5	12.1	2.2
4	28.2	2.7	21.8	2.5	11.7	2.2
5	29.2	2.4	22.1	2.5	12.4	2.2
6	30.2	2.6	20.8	2.3	12.2	2.2
7	31.0	2.3	21.2	2.4	13.0	2.0
8	28.0	2.5	23.6	2.5	13.7	2.3
9	46.5	2.6	26.4	2.7	15.6	2.4
10	39.3	3.1	31.4	2.7	16.4	2.4
11	39.8	2.4	36.3	2.8	15.5	2.6
12	38.8	2.5	36.6	2.8	14.5	2.3
13	36.7	2.5	30.5	2.9	14.2	2.4
14	38.2	2.6	23.6	2.7	14.6	2.4
15	35.2	2.5	19.5	2.7	13.7	2.3
16	33.6	2.5	19.8	2.5	12.3	2.9
17	33.9	2.4	17.7	2.5	10.1	2.9
18	32.1	2.7	17.3	2.5	9.0	2.2
19	30.2	2.6	19.3	2.5	11.2	2.3
20	32.5	2.6	21.0	2.4	10.3	2.3
21	40.8	2.7	20.3	2.6	12.6	2.4
22	50.4	2.4	20.8	2.5	10.8	2.5
23	51.1	2.6	21.5	2.3	12.9	2.3

2 PICKERING 1989

WPF vs TASR	GM	GSD
10.8	3.4	1.3
21.6	2.2	1.3
32.4	2.0	1.4
43.2	1.8	1.5
54.0	1.7	1.5
64.8	1.7	1.5
75.6	1.6	1.4
86.4	1.6	1.5
97.2	1.6	1.4
108.0	1.6	1.5
118.8	1.6	1.5
129.6	1.6	1.5
140.4	1.5	1.5
151.2	1.5	1.5
162.0	1.5	1.5
172.8	1.7	1.5
183.6	1.5	1.4
194.4	1.4	1.4
205.2	1.1	1.3
216.0	1.2	1.3
226.8	1.4	1.4
237.6	1.3	1.4
248.4	1.4	1.4
259.2	1.4	1.5
270.0	1.2	1.4
280.8	1.0	1.0
291.6	1.4	1.5
313.2	1.4	1.6
334.8	1.0	1.0

2 PICKERING 1989

WVB vs TASR	GM	GSD
0	2.3	1.6
1	2.4	1.6
2	2.4	1.6
3	2.5	1.5
4	2.6	1.5
5	2.6	1.5
6	2.6	1.5
7	2.6	1.5
8	2.6	1.5
9	2.6	1.5
10	2.5	1.5
11	2.4	1.5
12	2.4	1.6
13	2.4	1.6
14	2.4	1.6
15	2.5	1.5
16	2.6	1.5
17	2.6	1.5
18	2.6	1.5
19	2.6	1.6
20	2.5	1.6
21	2.5	1.6
22	2.4	1.5
23	2.3	1.5

2 PICKERING 1989

WVB vs TASR	GM	GSD
0	28.1	3.4
1	23.9	3.0
2	22.2	2.7
3	20.5	2.7
4	18.9	2.6
5	18.7	2.7
6	18.7	2.6
7	19.1	2.7
8	18.3	2.8
9	20.8	2.9
10	21.9	3.0
11	25.0	2.9
12	25.3	2.9
13	23.9	3.2
14	23.6	3.0
15	21.5	3.0
16	19.9	2.9
17	19.5	3.1
18	19.0	2.9
19	19.4	3.0
20	19.6	3.2
21	22.9	3.3
22	28.3	3.2
23	30.4	3.3

2 PICKERING 1989

WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	2.0	1.6	2.2	1.5	3.3	1.4
1	2.1	1.6	2.2	1.6	3.2	1.4
2	2.3	1.5	2.2	1.6	3.1	1.4
3	2.1	1.5	2.4	1.5	3.1	1.4
4	2.0	1.5	2.4	1.6	3.0	1.4
5	2.1	1.5	2.5	1.5	2.9	1.4
6	1.9	1.4	2.6	1.5	2.8	1.5
7	2.0	1.5	2.6	1.5	2.9	1.4
8	2.1	1.6	2.6	1.5	2.8	1.5
9	2.2	1.7	2.4	1.5	2.9	1.4
10	1.9	1.6	2.4	1.6	2.9	1.4
11	2.0	1.6	2.3	1.5	2.8	1.5
12	2.1	1.6	2.3	1.6	2.7	1.5
13	2.1	1.6	2.3	1.6	2.8	1.4
14	2.2	1.6	2.3	1.6	2.8	1.5
15	2.1	1.5	2.5	1.6	3.1	1.4
16	2.1	1.6	2.6	1.5	3.2	1.4
17	2.5	1.6	2.6	1.5	3.1	1.3
18	2.2	1.6	2.8	1.5	2.9	1.4
19	2.3	1.5	2.6	1.6	2.8	1.5
20	2.2	1.5	2.5	1.6	3.0	1.5
21	2.1	1.6	2.5	1.5	2.9	1.5
22	2.0	1.5	2.3	1.5	3.0	1.4
23	1.9	1.6	2.2	1.5	3.0	1.4

2 PICKERING 1989
WVB vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	41.6	3.4	35.7	2.9	9.4	2.6
1	38.0	2.6	27.6	2.9	11.3	2.7
2	31.2	2.4	26.4	2.6	12.2	2.5
3	31.6	2.3	23.8	2.5	11.9	2.5
4	34.5	2.4	20.6	2.5	12.9	2.6
5	33.0	2.2	22.1	2.6	12.2	2.6
6	39.5	1.8	21.0	2.7	13.3	2.4
7	38.9	2.1	20.5	2.7	14.0	2.5
8	32.9	2.7	21.3	2.7	13.0	2.8
9	34.2	3.4	24.1	2.8	14.7	2.6
10	48.6	2.9	25.3	2.8	13.5	2.8
11	36.0	2.5	30.2	2.7	16.1	2.9
12	35.5	3.4	29.3	2.7	16.1	2.7
13	35.0	3.6	25.3	3.3	16.8	2.6
14	40.7	3.3	24.5	2.8	15.4	2.8
15	39.8	2.9	22.1	2.9	12.2	2.7
16	37.1	2.7	19.8	2.7	10.8	2.7
17	28.6	2.9	20.2	2.9	11.9	3.7
18	34.3	2.8	16.4	2.7	12.6	2.8
19	31.5	2.9	18.6	2.9	12.7	3.1
20	33.6	2.8	19.5	3.0	10.4	3.1
21	38.3	2.8	24.2	2.9	11.3	3.9
22	44.3	2.8	33.5	2.8	10.9	3.2
23	56.3	2.9	33.6	3.0	11.9	3.1

5 EAST POINT 1989

WPF vs WVB	GM	GSD
10.8	3.4	1.3
21.6	2.2	1.3
32.4	2.0	1.4
43.2	1.8	1.4
54.0	1.6	1.5
64.8	1.7	1.5
75.6	1.7	1.5
86.4	1.7	1.5
97.2	1.4	1.4
108.0	1.5	1.5
118.8	1.4	1.5
129.6	1.5	1.5
140.4	1.5	1.5
151.2	1.4	1.5
162.0	1.5	1.5
172.8	1.5	1.5
183.6	1.2	1.4
194.4	1.2	1.4
205.2	1.4	1.4
216.0	1.2	1.3
226.8	1.4	1.4
237.6	1.4	1.4
248.4	1.0	1.0
259.2	1.1	1.3
270.0	1.0	1.0
280.8	1.6	1.5
291.6	1.3	1.5
302.4	1.0	1.0
313.2	1.0	1.0
324.0	2.0	0.0
334.8	1.6	1.5

5 EAST POINT 1989

WPF vs TASR	GM	GSD
0	2.2	1.6
1	2.4	1.6
2	2.5	1.6
3	2.6	1.5
4	2.7	1.5
5	2.6	1.5
6	2.6	1.5
7	2.5	1.6
8	2.5	1.6
9	2.4	1.5
10	2.4	1.6
11	2.4	1.6
12	2.4	1.5
13	2.5	1.6
14	2.4	1.6
15	2.4	1.6
16	2.5	1.6
17	2.6	1.5
18	2.6	1.5
19	2.6	1.6
20	2.5	1.6
21	2.3	1.6
22	2.2	1.6
23	2.2	1.6

5 EAST POINT 1989

WVB vs TASR	GM	GSD
0	29.3	3.3
1	25.0	2.8
2	21.9	2.9
3	19.4	2.7
4	18.9	2.6
5	18.9	2.5
6	19.7	2.6
7	19.7	2.7
8	20.7	2.8
9	23.3	2.7
10	24.3	2.8
11	25.1	2.8
12	24.2	2.9
13	24.7	3.1
14	24.5	3.0
15	23.6	2.9
16	21.6	2.9
17	20.2	2.8
18	19.1	2.9
19	20.0	3.1
20	21.2	3.1
21	26.6	3.1
22	32.3	3.2
23	33.3	3.2

5 EAST POINT 1989

WPF vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	1.9	1.6	2.2	1.6	3.2	1.4
1	2.1	1.6	2.3	1.6	3.1	1.4
2	2.1	1.6	2.4	1.5	3.1	1.4
3	2.3	1.5	2.5	1.5	3.0	1.5
4	2.1	1.6	2.6	1.5	3.2	1.4
5	2.2	1.5	2.5	1.5	3.1	1.4
6	2.1	1.5	2.4	1.5	3.1	1.4
7	1.6	1.5	2.5	1.6	2.9	1.5
8	1.8	1.7	2.4	1.6	2.9	1.4
9	1.8	1.6	2.3	1.5	2.8	1.5
10	1.9	1.5	2.3	1.6	2.8	1.5
11	2.0	1.7	2.3	1.6	2.7	1.5
12	1.9	1.6	2.4	1.5	2.9	1.4
13	2.1	1.6	2.4	1.6	3.0	1.5
14	2.1	1.6	2.4	1.6	3.0	1.5
15	2.0	1.6	2.5	1.6	3.0	1.5
16	2.0	1.6	2.5	1.5	3.2	1.3
17	2.3	1.6	2.6	1.5	3.2	1.4
18	2.1	1.6	2.8	1.5	3.2	1.4
19	2.1	1.6	2.7	1.5	3.3	1.4
20	2.0	1.6	2.6	1.5	3.1	1.5
21	2.0	1.6	2.3	1.6	3.0	1.5
22	2.0	1.6	2.2	1.6	2.9	1.5
23	1.9	1.6	2.2	1.6	3.0	1.4

5 EAST POINT 1989
WVB vs TASR by Wind Speed, u (GM, GSD)

	$u \leq 2$ m s^{-1}		$2 \leq u \leq 5$ m s^{-1}		$u > 5$ m s^{-1}	
0	51.5	2.4	31.3	3.0	10.3	3.5
1	34.2	2.6	28.0	2.8	12.1	2.4
2	33.0	2.7	23.5	2.8	11.3	2.4
3	29.5	2.5	20.2	2.7	12.9	2.6
4	33.8	2.3	20.3	2.5	12.3	2.3
5	34.7	2.3	20.6	2.5	12.9	2.3
6	37.3	2.6	22.8	2.6	13.5	2.2
7	54.2	2.1	22.1	2.6	13.4	2.4
8	45.6	2.5	23.6	2.6	14.3	2.6
9	58.1	2.3	25.4	2.4	14.7	2.7
10	48.8	2.4	25.4	2.8	16.3	2.5
11	37.1	2.9	28.7	2.6	15.9	2.7
12	47.7	2.8	25.3	2.7	13.7	2.6
13	44.0	3.1	25.9	2.8	12.4	2.5
14	39.8	2.9	24.2	2.9	13.9	2.7
15	40.1	2.8	23.2	2.7	12.0	2.3
16	38.5	2.7	20.2	2.8	10.7	2.1
17	30.3	3.0	19.6	2.7	11.1	2.2
18	34.1	2.7	16.7	2.7	9.8	2.1
19	35.7	2.6	17.8	2.7	9.3	3.7
20	38.8	2.5	19.2	2.9	10.1	2.9
21	45.3	2.8	25.8	2.8	12.8	3.0
22	54.3	2.9	34.9	2.8	12.5	3.0
23	56.1	2.8	35.5	3.0	13.2	2.7